Aliceville Reservoir Dissolved Oxygen TMDL Model Report

September 2007

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1 Introduction to Aliceville Reservoir Dissolved Oxygen TMDL Model

This report documents the development of water quality models that will be used as tools for establishing Total Maximum Daily Loads (TMDLs) to address the dissolved oxygen impairment of the Tombigbee River and the Aliceville Reservoir Pool between Stennis Lock and Dam and Bevill Lock and Dam in Mississippi and Alabama (see Figure 1). These modeling tools include: 1) an application of the watershed model, BASINS PLOAD; 2) an application of the hydrodynamic, three-dimensional model, EFDC; and 3) an application of the Water Quality Analysis Program (WASP) 7.2 eutrophication model.

2 Characterization of Point and Non-Point Pollution Sources

The watersheds upstream of Aliceville Reservoir are shown in Figure 1. Landuse of the watersheds is shown in Table 1. The landuse of the Aliceville watersheds is predominantly agriculture, forest and wetlands.

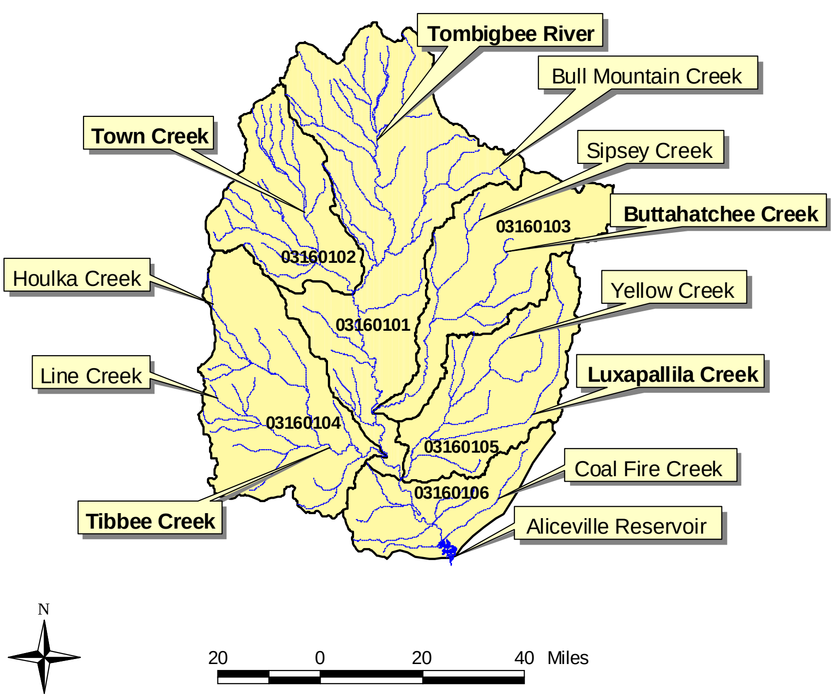


Figure 1: Watersheds Upstream of Aliceville Reservoir

Table 1: NLCD Landuse in Acres for Watersheds Upstream of Aliceville Reservoir.

	3160105	3160106	3160101	3160104	3160103	3160102
	LUXAPALLILA	MIDDLE TOMBIGBEE-LUBBUB	UPPER TOMBIGBEE	TIBBEE	BUTTAHATCHEE	TOWN
Agriculture - Cropland	41175	188005	163641	167024	32572	98762
Agriculture - Pasture	42566	134216	170037	153196	39774	135302
Barren or Mining	238	1077	910	650	544	208
Forest	364342	485116	642021	295845	408270	181173
Transitional	13278	18909	38760	7987	27322	2032
Urban	5980	4031	11700	8333	4187	15809
Water/Wetlands	41399	213679	126868	71103	45751	11232

Alabama Department of Environmental Management (ADEM) and Mississippi Department of Environmental Quality (MDEQ) maintain databases of current National Pollutant Discharge Elimination System (NPDES) permits and geographic information system (GIS) files that locate each permitted outfall. These databases include municipal, semi-public/private, industrial, mining, industrial storm water, and concentrated animal feeding operations (CAFOs) permits. There are a total of 166 Mississippi and Alabama NPDES permits with biochemical oxygen demand (BOD) effluent limitations in Tombigbee River hydrologic code units (HUCs) 03160101 through 03160106 (USEPA PCS Query, 8/13/07). The majority of these permits are for small facilities.

There are ten major dischargers with NPDES BOD effluent limits within the six HUCs upstream of Aliceville Reservoir. Two dischargers without BOD limits (EKA Chemical, and Sanderson) are also included because of proximity to the reservoir. EKA Chemical, which manufactures hydrogen peroxide and sodium chlorate (according to MDEQ), has a total organic carbon (TOC) limit and reports BOD concentration of its effluent. Sanderson manufactures wood products and also reports its effluent BOD concentration. The two major dischargers closest to Aliceville reservoir are Columbus POTW and Weyerhaeuser Company Columbus Pulp and Paper Complex (CPPC). These dischargers are summarized in Table 2 and Figure 2.

Table 2: Major NPDES Permitted Discharges of BOD and Ammonia to the Tombigbee River Upstream of Aliceville Dam.

NPDES Permit #	Facility Name	Facility Type	Flow (MGD)	5- day BOD Limit (lb/d)	Ammonia (lb/d)
MS0001783	Bryan Foods	Meat Packing	2.65 [f]	375 [a]	50 / 44 [h]
MS0003158	True Temper Sports/Emhart	Plating	0.346 [m]	78[b]	0.033[L]
MS0045489	Amory POTW	Sewerage	2	751	33[k]
MS0055581	Aberdeen POTW	Sewerage	4	1501,1001[c]	58[f]
AL0048372	Hamilton POTW	Sewerage	2.64 [f]	352	132
MS0020788	West Point POTW	Sewerage	3.5	525 [i] / 876 [j]	58[k]
MS0036111	Tupelo POTW	Sewerage	10.5	2,627	175 [i] / 350 [j]
AL0023400	Winfield POTW	Sewerage	0.353 [f]	225 / 183 [g]	76.7/49.2 [g]
MS0056472	Columbus POTW	Sewerage	10	2,168	500
MS0036412	Weyerhaeuser CPPC	Paper Mill	19 [f]	21,954[d]	192 [f]
MS0040215	EKA Chemical	Chemical	0.655 [f]	32[f]	NA
MS0002216	Sanderson	Wood Products	0.23 [f]	3.3[f]	NA

a. Permitted $CBOD_5$ limit.
b. No BOD_5 limit for pipe 1; table shows average discharge from 8/05 to 12/06.
c. Permitted BOD_5 limit was 1501 through Dec. 2004, then 1001 Jan. 2005 through present.
d. Variable limit based on temperature and flow conditions of the Tombigbee River, table shows monthly average permitted discharge.
e. No BOD limit specified, has a permitted TOC limit of 73 lb/d as of Nov. 2005.
f. No permit limit; table shows average discharge from 1/03 to 12/06.
g. 2003-Aug. 2006 limit, then Sep. 2006 to present limit.
h. 2003-July. 2006 limit, then Aug. 2006 to present limit.
i. Summer limit (May – Oct..)
j. Winter limit (Nov. –Apr.).
k. Estimated ammonia from permitted discharge and assumed ammonia conc. of 2 mg/l.
l. Estimated ammonia from pipe #2 0.002 MGD discharge and assumed ammonia conc. of 2 mg/l.
m. Design flow.

Table 3: Existing Discharge (2003-2006) for Major NPDES Facilities to the Tombigbee River Upstream of Aliceville Dam.

Facility Name	Facility Type	5- day BOD (lb/d)	Ammonia (lb/d)	TN (lb/d)	TP (lb/d)
Bryan Foods	Meat Packing	51	7	1297	598
True Temper Sports/Emhart	Plating	78	0.033	0	14
Amory POTW	Sewerage	108	13	83	54
Aberdeen POTW	Sewerage	188	58	377	32
Hamilton POTW	Sewerage	25	1.2	8	64
West Point POTW	Sewerage	66	58	189	17
Tupelo POTW	Sewerage	584	8	49	353
Winfield POTW	Sewerage	22	34	223	5
Columbus POTW	Sewerage	245	34	480	65
Weyerhaeuser CPPC	Paper Mill	2,659	192	700	191
EKA Chemical	Chemical	32	5.3	7.2	7
Sanderson	Wood Products	3.3	NA	NA	NA

Table 4: Existing discharge as percent of Permit Limit for Major NPDES Facilities of BOD and Ammonia to the Tombigbee River Upstream of Aliceville Reservoir.

HUC	NPDES Permit #	Facility Name	Facility Type	5- day BOD Limit (lb/d)	Ammonia (lb/d)
03160101	MS0001783	Bryan Foods	Meat Packing	14%	16%
03160101	MS0003158	True Temper Sports/Emhart	Plating	NA	NA
03160101	MS0045489	Amory POTW	Sewerage	14%	39%
03160101	MS0055581	Aberdeen POTW	Sewerage	19%	NA
03160103	AL0048372	Hamilton POTW	Sewerage	7%	1%
03160104	MS0020788	West Point POTW	Sewerage	13%	50%
03160102	MS0036111	Tupelo POTW	Sewerage	22%	5%
03160105	AL0023400	Winfield POTW	Sewerage	12%	69%
03160105	MS0056472	Columbus POTW	Sewerage	11%	7%
03160106	MS0036412	Weyerhaeuser CPPC	Paper Mill	12%	NA
03160106	MS0040215	EKA Chemical	Chemical	NA	NA
03160105	MS0002216	Sanderson	Wood Products	NA	NA

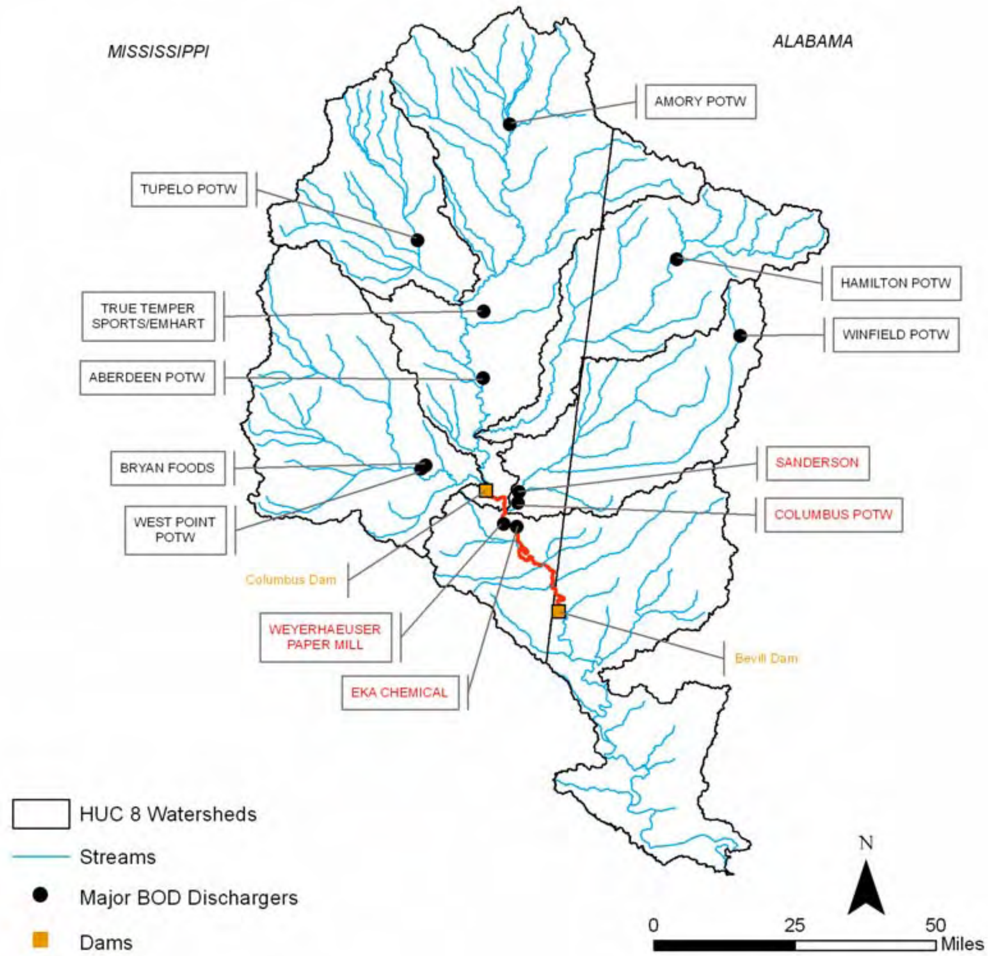


Figure 2: Major Discharges of BOD to the Tombigbee River Above Bevill Dam

The other eight of these major discharges are farther from Aliceville reservoir. Seven are upstream of Stennis Lock and Dam at Columbus and one is far upstream on Luxapallila Creek. These eight dischargers have a total 5-day BOD limit of 5884 pounds per day and an ammonia limit of 549 pounds per day. The four dischargers closer to Aliceville reservoir have a combined 5-day BOD limit of 4846 pounds per day and an ammonia limit of 692 pounds per day. However, much of the distant discharged BOD and nutrient load will be consumed or settled-out prior to reaching Aliceville Reservoir. The loads from these facilities are a part of model boundary conditions, although these eight discharges are not explicitly in the model. To understand the contribution to the boundary pollution loads from these facilities, load estimations outside of the water quality model were calculated. These estimations are based on distance from the model boundary, flow velocity, and pollutant decay.

The BOD load delivered to the Aliceville pool from the distant, eight dischargers is estimated to be about 33 percent of the actual discharged load due to decay. This ultimately contributes only 1 percent of the total loading to Aliceville reservoir. This remaining load was estimated according to the low flow conditions observed during the August 2005 water quality survey. This survey included current monitoring and a dye tracer study, and revealed an average current velocity of 0.19 feet per second for the Tombigbee and a velocity of 0.2 to 0.6 feet per second in the Luxapallila. These velocities and the distance from the Aliceville pool were used to determine the travel time from each major discharge. A BOD decay rate of 0.06 per day, which is typical for waters in this area, was used to determine the remaining BOD at the Aliceville pool.

Long term BOD test revealed a nitrogenous (NBOD) decay rate of 0.16 per day, which was used to estimate the remaining oxygen demand from nitrogen discharged by these point sources. Ammonia nitrogen was reported by most facilities, and a concentration of 2 mg/l was assumed for those that did not report. Also, total nitrogen was estimated as 15 mg/l based on a range of total nitrogen in wastewater effluents of 11 to 22 reported in the EPA Technical Guidance Manual for Performing Wasteload Allocations, Book II: Streams and Rivers –Part 1: Biochemical Oxygen Demand/Dissolved Oxygen and Nutrients/Eutrophication, EPA DOCUMENT NUMBER: EPA-823-B-97-002, March 1997. The nitrogen load delivered from these distant dischargers to the Aliceville pool is less than 35 percent of the discharged load due to mineralization and nitrification (NBOD decay). This nitrogen load ultimately contributes about 3 percent of the nitrogen load in Aliceville reservoir. Figure 3 shows the portion of the BOD and total nitrogen loads delivered to Aliceville reservoir by the distant sources and nearby sources.

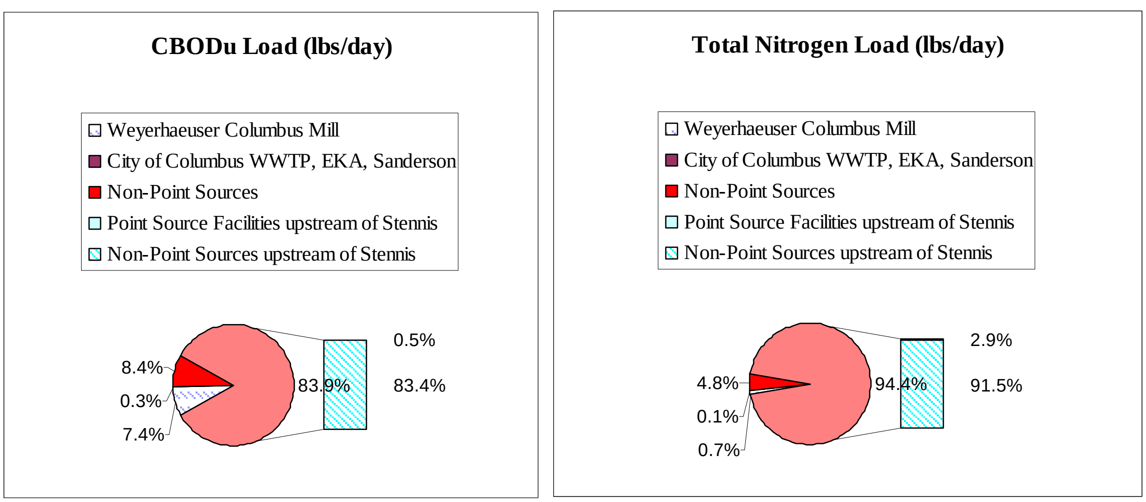


Figure 3: Existing BOD and TN contribution from near and far sources.

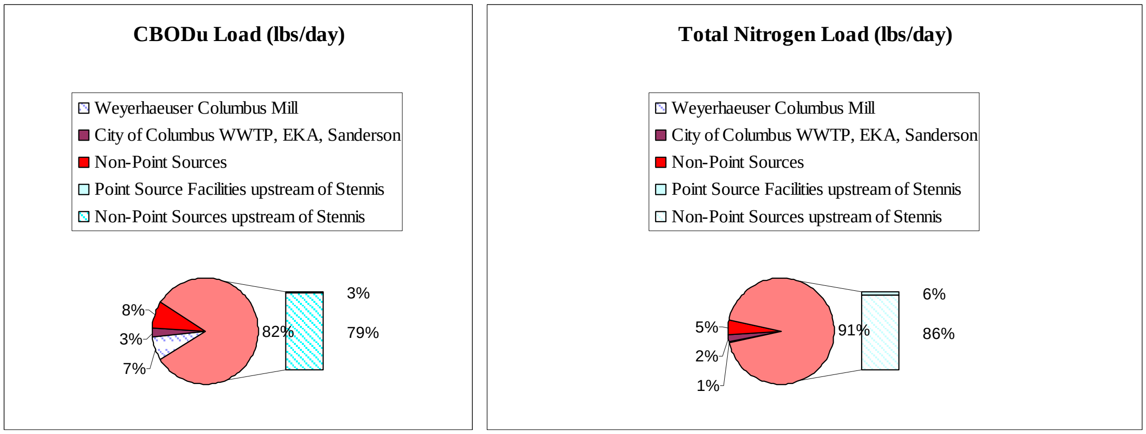


Figure 4: Permitted BOD and TN loads.

Although there are no permit limits for phosphorus discharges, these facilities also discharge a combined 1772 pounds per day of phosphorus to the watershed. This is also shown in Table 3. Of this phosphorus load, about 1479 pounds per day is from the distant discharges. The local facilities (City of Columbus WWTP, Weyerhaeuser, Eka Chemical) discharge about 293 pounds per day of phosphorus into Aliceville Reservoir. Assuming that two thirds of the distant phosphorus load is used by plants or settles out by the time it reaches Stennis Dam, about one third or 493 pounds per day can be expected to enter Aliceville Reservoir. An additional 528 pounds per day is estimated to enter Aliceville Reservoir from non-point sources upstream of Stennis. Downstream non-point sources are expected to contribute an additional 288 pounds per day of total phosphorus to the reservoir system. These loads are summarized in Figure 5.

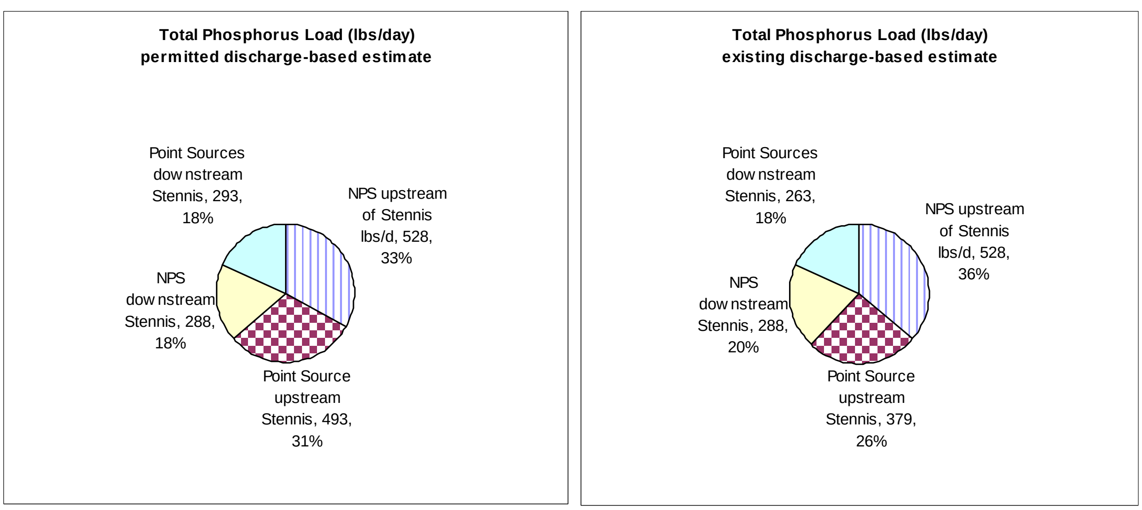


Figure 5: Total Phosphorus Loads to Aliceville Reservoir: estimates for permitted and for existing loads.

The upstream major dischargers, as well as non-point sources, are treated as part of the headwater load at Stennis Dam in the models. The point sources and non-point sources downstream of Stennis are entered at the outfall location and tributary locations in the models.

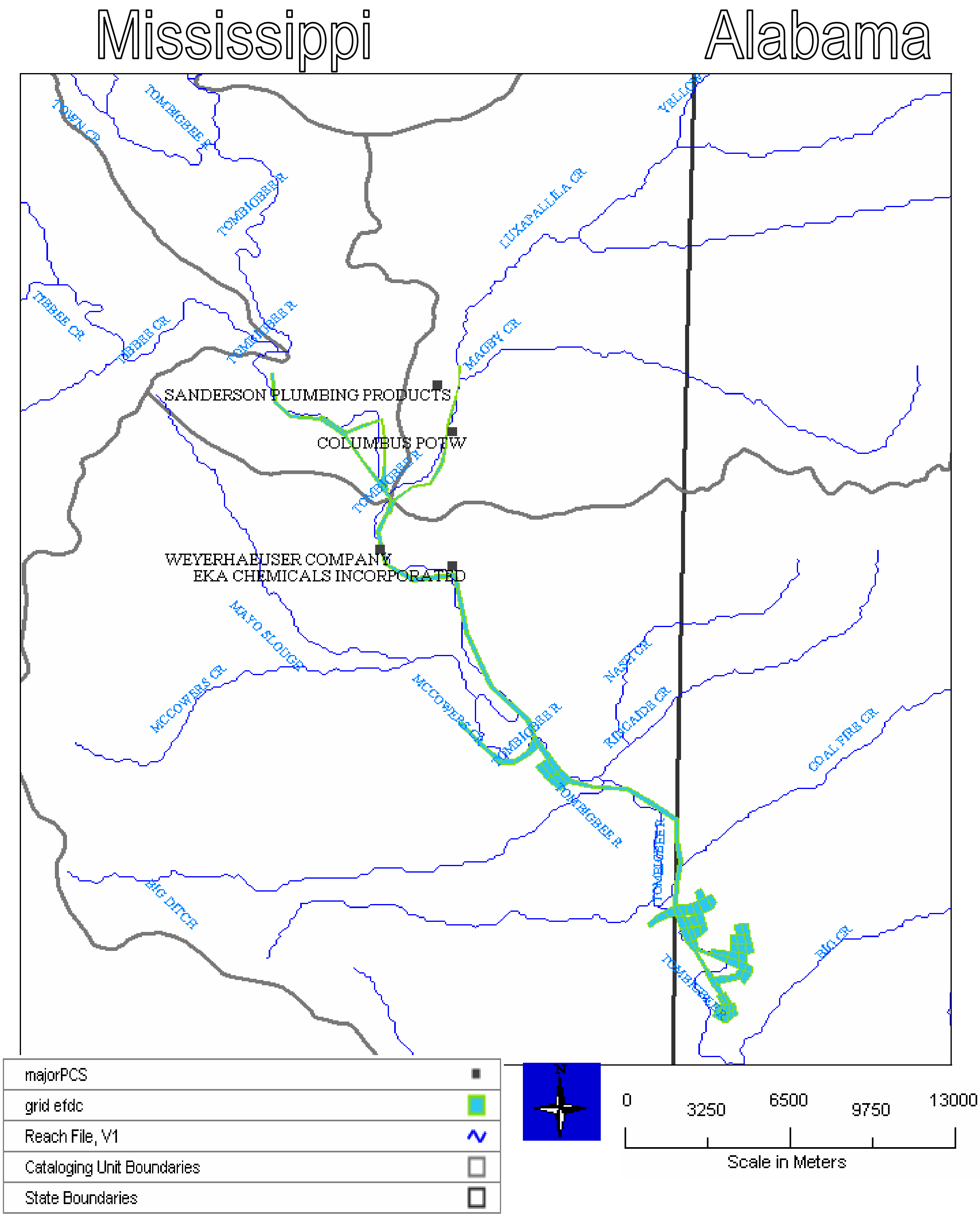


Figure 6: Major Point Sources Near Aliceville Reservoir

3 Water Quality Data

Water quality data from Mississippi Department of Environmental Quality (MDEQ), Alabama Department of Environmental Management (ADEM), Environmental Protection Agency Science and Ecosystem Support Division (EPA SESD), and Weyerhaeuser Company was used to characterize this reservoir and calibrate the models. A list of stations is shown in Table 5 and the locations are shown in Figure 20.

Table 5: Water Quality Stations in Aliceville Reservoir

Station	Agency	Station Name	First Date	Last Date
1A	ADEM	Lower Aliceville Reservoir, deepest point in main river channel	05/13/1992	10/31/2006
2A	ADEM	Upper Aliceville Reservoir near state line	04/19/2001	10/31/2006
3A	ADEM	Aliceville Reservoir Coal Fire Creek Embayment	04/19/2001	10/31/2006
AVP01	MDEQ	Aliceville pool at state line	06/24/2003	09/28/2004 11:30
AVP02	MDEQ	Aliceville pool at Greens Creek	06/24/2003	09/28/2004
AVP03	MDEQ	Aliceville pool below Luxapalilla Creek	06/24/2003	09/28/2004
CFO25	EPA	Coal Fire Creek	08/14/2005	08/16/2005
JC315S	EPA	James Creek at Tenn-Tom Waterway river mile 315.8	08/13/2005	08/15/2005
LCO2	EPA	Luxapallila Creek near mouth	08/13/2005	08/15/2005
TT304	EPA	Tenn-Tom Waterway downstream of Bevill Lock & Dam	08/15/2005	08/17/2005
TT307	EPA	Tenn-Tom Waterway in Aliceville Pool	08/15/2005	08/17/2005
TT310	EPA	Tenn-Tom Waterway near MS-AL state line	08/15/2005	08/17/2005
TT314	EPA	Tenn-Tom Waterway near US 49 Bridge	08/15/2005	08/17/2005
TT319	EPA	Tenn-Tom Waterway near Harrison Bend	08/13/2005	08/15/2005
TT324	EPA	Tenn-Tom Waterway below Weyerhaeuser	08/13/2005	08/15/2005
TT327	EPA	Tenn-Tom Waterway above Weyerhaeuser near marker buoy	08/13/2005	08/15/2005
TT332	EPA	Tenn-Tom Waterway near Highway 82 Bridge	08/13/2005	08/15/2005
TT336	EPA	Columbus Pool near Stennis Lock & Dam	08/11/2005	08/13/2005
TT340	EPA	Tenn-Tom Waterway near Highway 50 Bridge	08/15/2005	08/17/2005
TTFA02S	EPA	Tenn-Tom Waterway Flow Augmentation Channel	08/11/2005	08/13/2005

327.8	Weyerhaeuser	Tenn-Tom at river mile 327.8	08/01/2003	10/24/2006
327.0	Weyerhaeuser	Tenn-Tom at river mile 327.0	08/01/2003	10/24/2006
316.3	Weyerhaeuser	Tenn-Tom at river mile 316.3	08/01/2003	10/24/2006
308.1	Weyerhaeuser	Tenn-Tom at river mile 308.1	08/01/2003	10/24/2006
1A	Weyerhaeuser	ADEM station 1A at Aliceville Dam forebay	08/01/2003	10/24/2006
2A	Weyerhaeuser	ADEM station 1A at state line	08/01/2003	10/24/2006

Water quality data from 2003 through 2006 for Aliceville reservoir is presented next. The DO measured at a depth of five feet at Aliceville Dam sagged each summer and fell below the water quality criterion of 5.0 mg/l in 2003, 2004 and 2006 (see Figure 7). The DO about 3 miles upstream near the stateline followed a similar cycle with a summer sag, however it remained above 5.0 mg/l (see Figure 8).

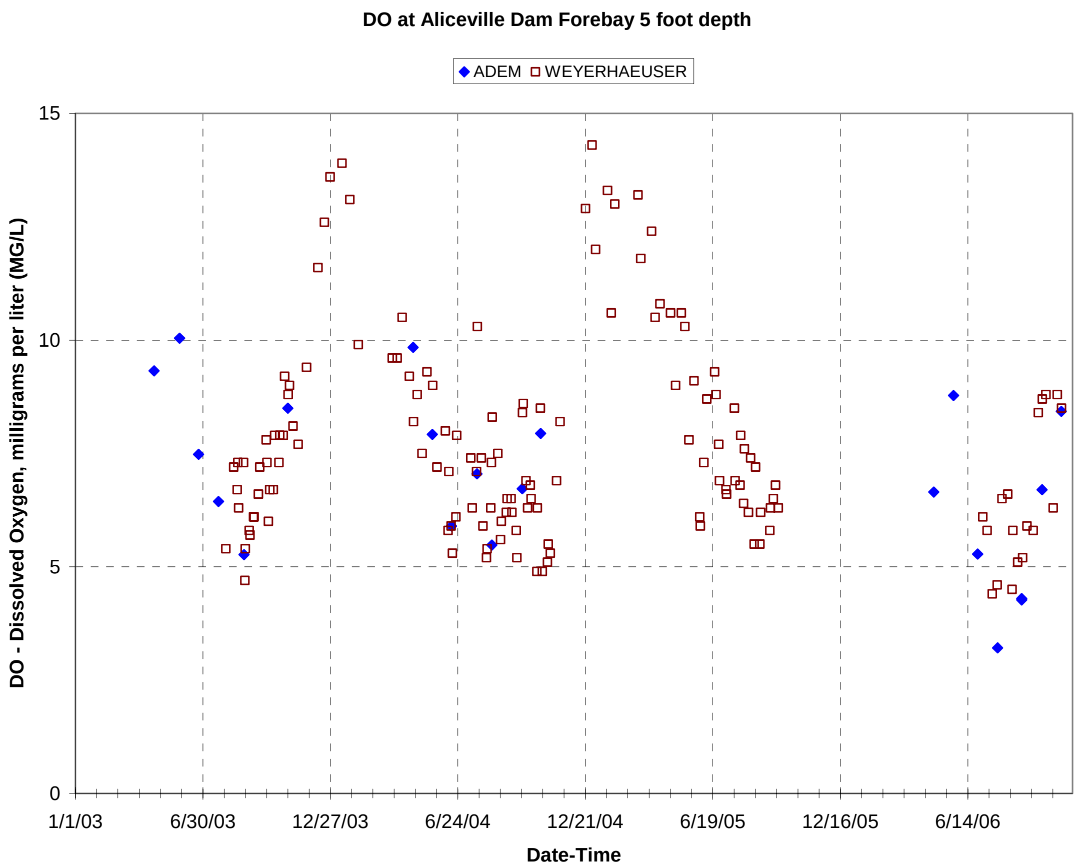


Figure 7: DO at Aliceville Dam

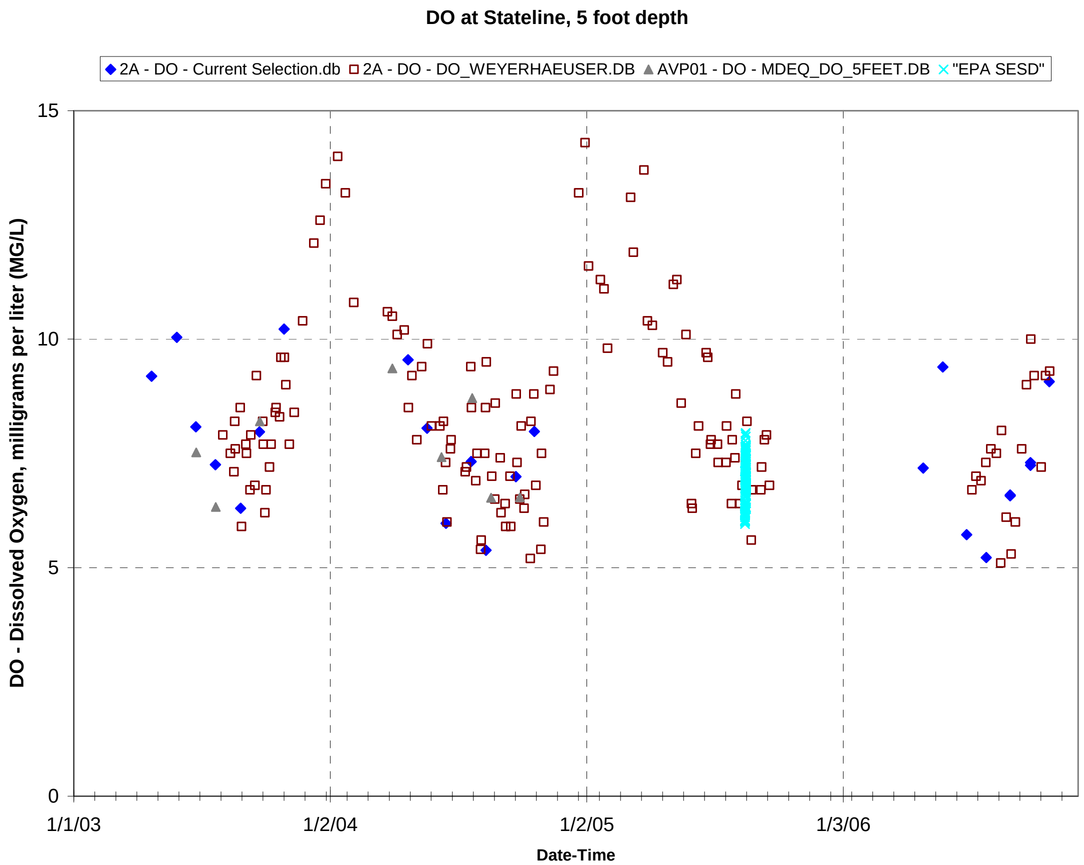
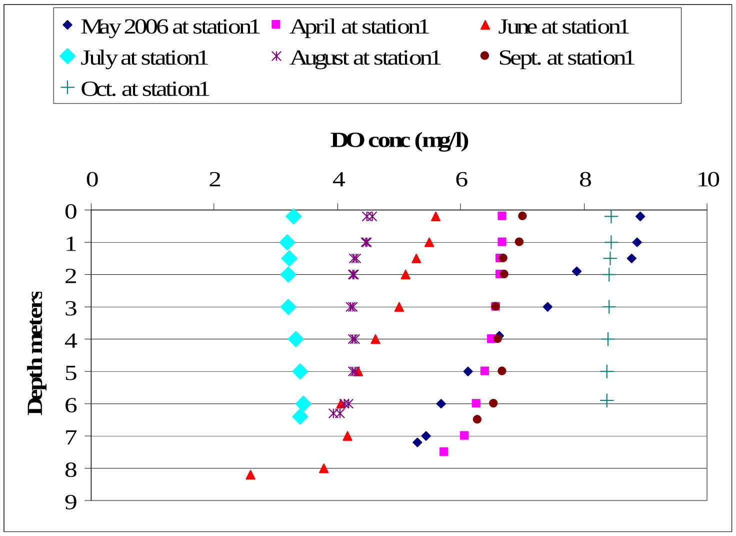
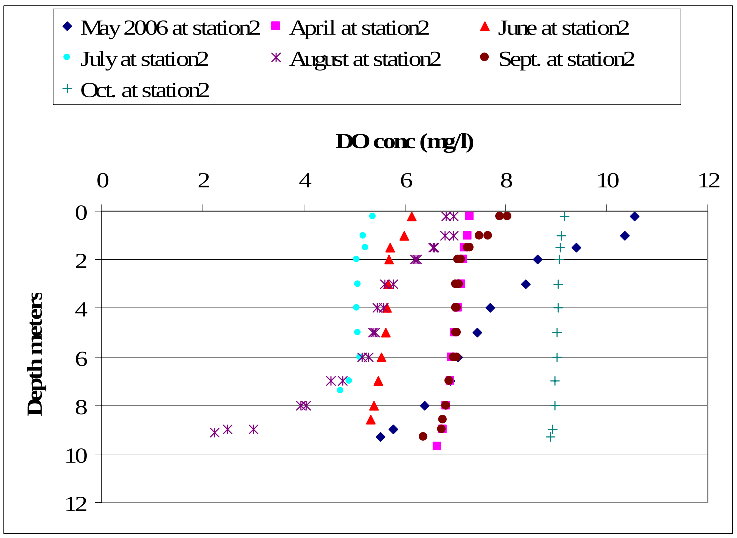


Figure 8: DO at stateline

Review of 2006 DO vertical profile data shows the DO stratifies at certain times depending on the location (see Figure 9). At station 1 near Bevill Dam (Aliceville Dam), the DO is well mixed in April, 2006 and stratified in May and June before mixing again in July. This stratification likely occurs when there is little flow to mix the reservoir, then gets well mixed during flow events. Figure 10 shows that the temperature is not stratified much at any time and so, is not the cause of the DO stratification. Most likely plant production in the photic zone and oxygen depletion due to SOD in the bottom sediments in the lower layer of the reservoir causes the stratification. Once enough flow is generated, the water column mixes and evens out the DO throughout the profile. During the water quality study in August 2005 mild DO stratification was observed at all stations. This is shown on pages 15 through 18 of the EPA water quality study report.





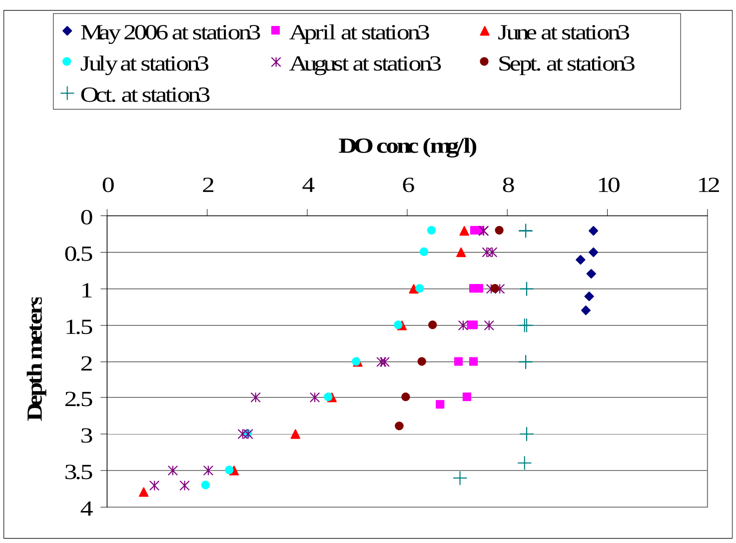


Figure 9: 2006 DO vertical profiles.

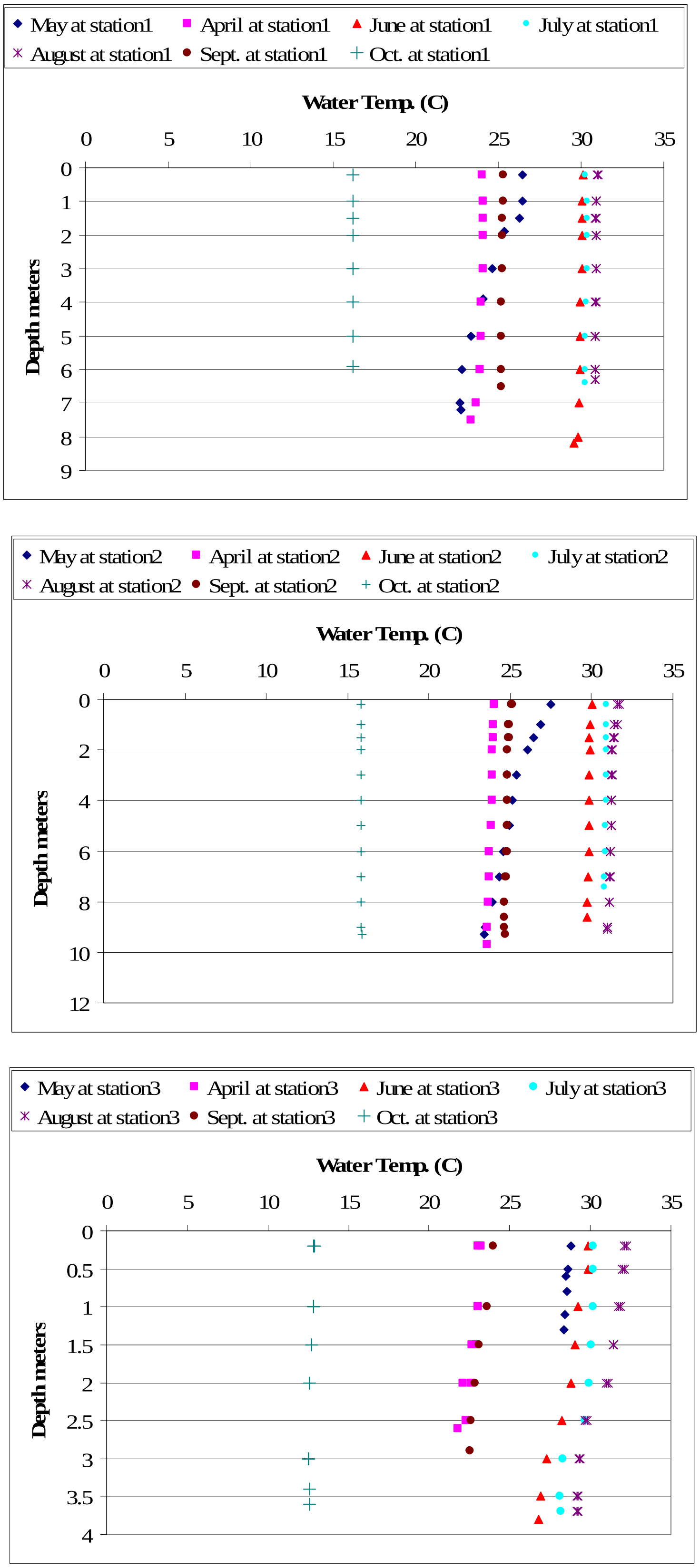


Figure 10: 2006 Temperature vertical profiles.

There was no trend monitoring for biochemical oxygen demand prior to 2006. However, total organic carbon (TOC) was measured routinely and EPA SESD measured both TOC and BOD during their field study in 2005. In order to see the BOD trend, CBOD was estimated from the relationship between TOC and CBOD. Figure 11 and Figure 12 show the measured 5-day CBOD collected by ADEM as well as the ultimate CBOD estimated from TOC. The ultimate CBOD from EPA's longterm tests are also shown. This CBOD concentration of around 10 mg/l is a relatively high oxygen demand in this reservoir.

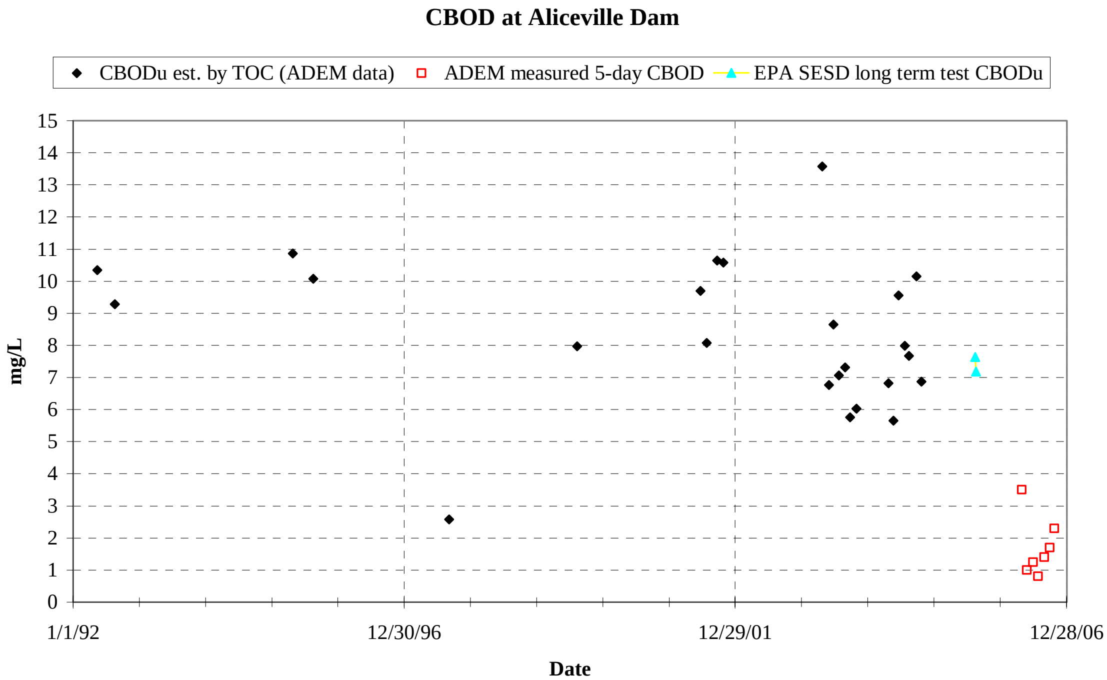


Figure 11: CBOD at Aliceville Dam

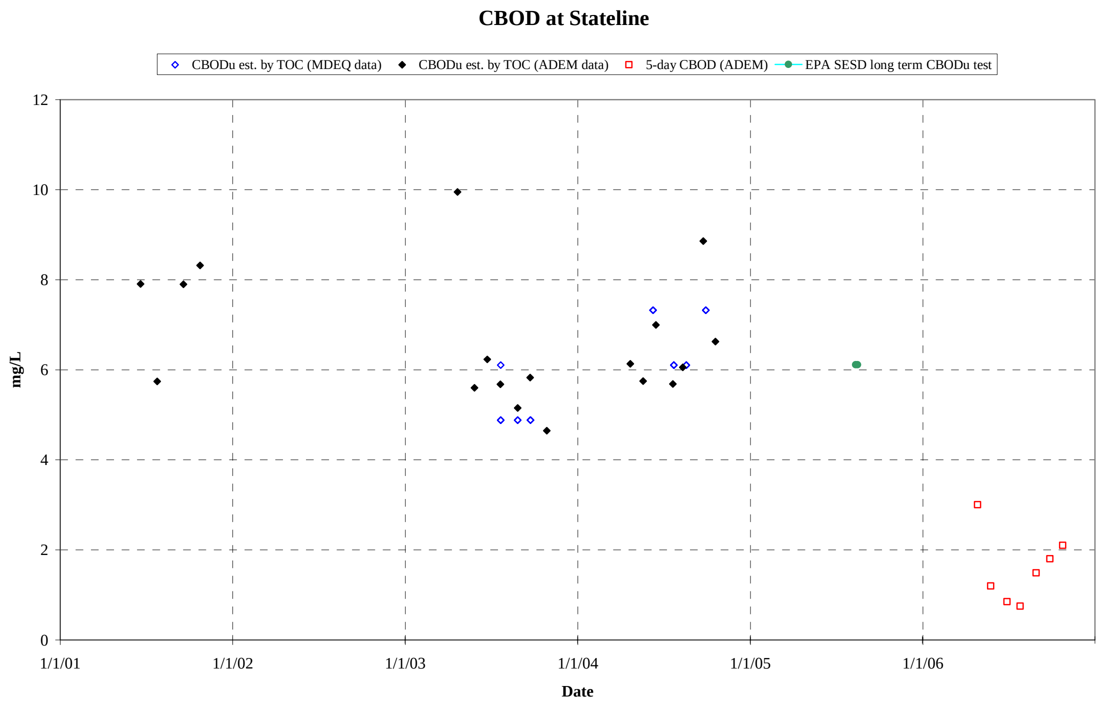


Figure 12: CBOD at Stateline

Nitrogen at Aliceville Dam is shown in Figure 13. Trend lines are shown to demonstrate the relative fraction of ammonia, nitrate-nitrite, and organic nitrogen of the total nitrogen. Ammonia levels constitute the lowest fraction of total nitrogen, and organic nitrogen makes up most of the nitrogen. The ammonia level is low at 0.027 mg/l compared to the Alabama, Southeastern Temperate Forested Plains and Hills Ecoregion concentration for reservoirs of 0.075 mg/l (USEPA, 2000). The average TKN at Aliceville Dam, which is mainly organic nitrogen, is 0.467 mg/l and is higher than the average TKN of 0.370 mg/l in the ecoregion. Total phosphorus and dissolved reactive phosphorus concentrations are shown in Figure 14 at Aliceville Dam. The average total phosphorus in Aliceville reservoir is 0.087 mg/l which is about two times the ecoregion value of 0.046 mg/l. The chlorophyll-a measured in Aliceville reservoir at the dam and stateline are shown in Figure 15 and Figure 16, respectively. The average chlorophyll-a at Aliceville Dam shown in Figure 15 is 15.8 ug/l, and the average at the stateline shown in Figure 16 is 15.6 ug/l. These are almost two times the ecoregion average chlorophyll-a concentration for reservoirs of 7.8 ug/l.

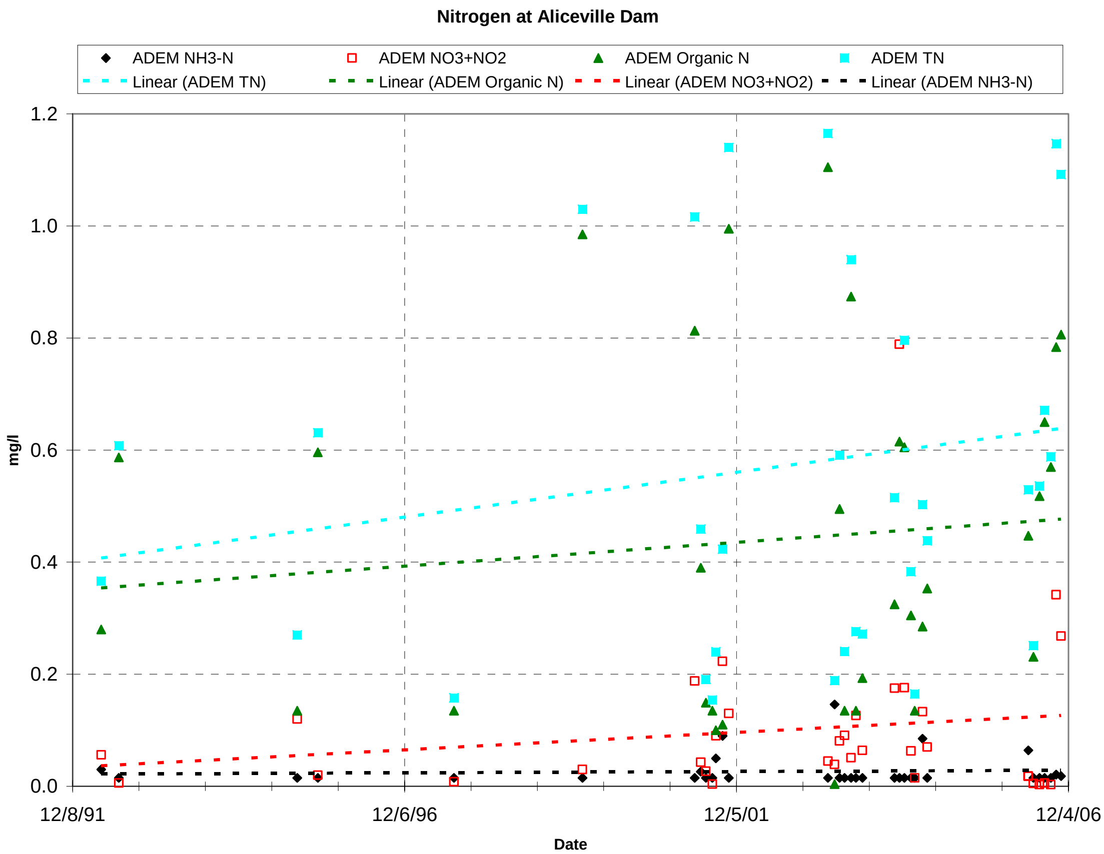


Figure 13: Nitrogen at Aliceville Dam

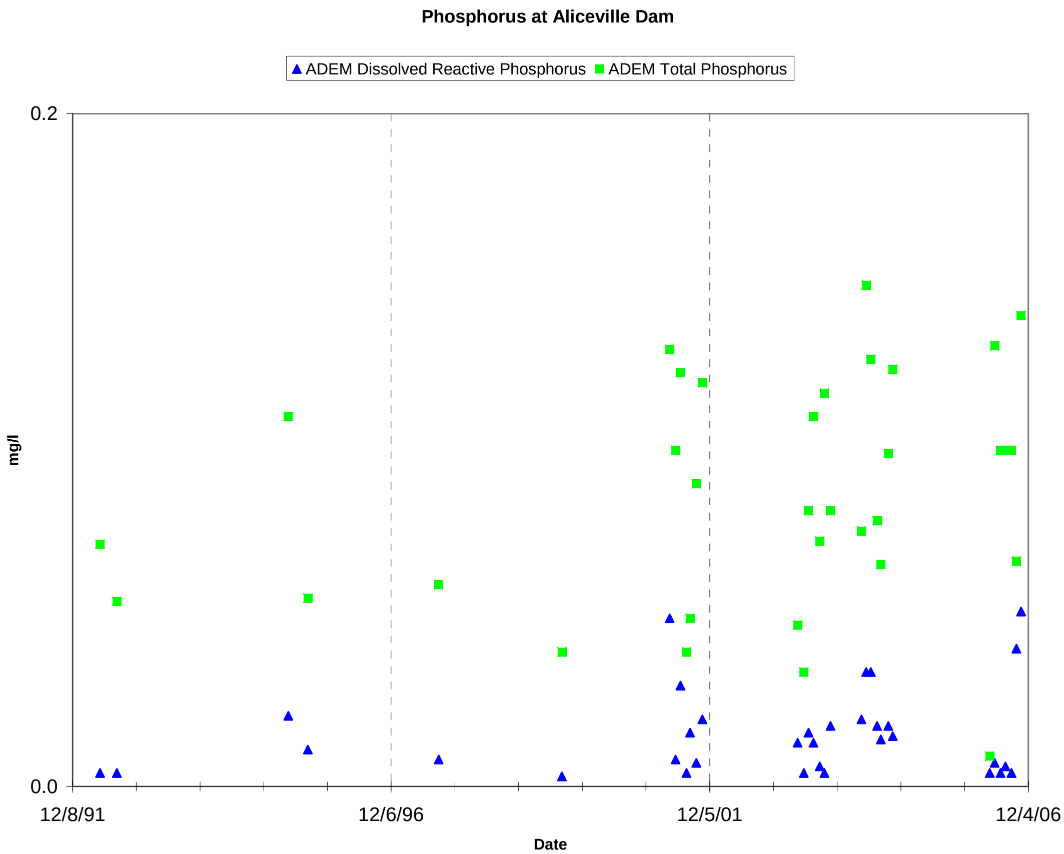


Figure 14: Phosphorus at Aliceville Dam

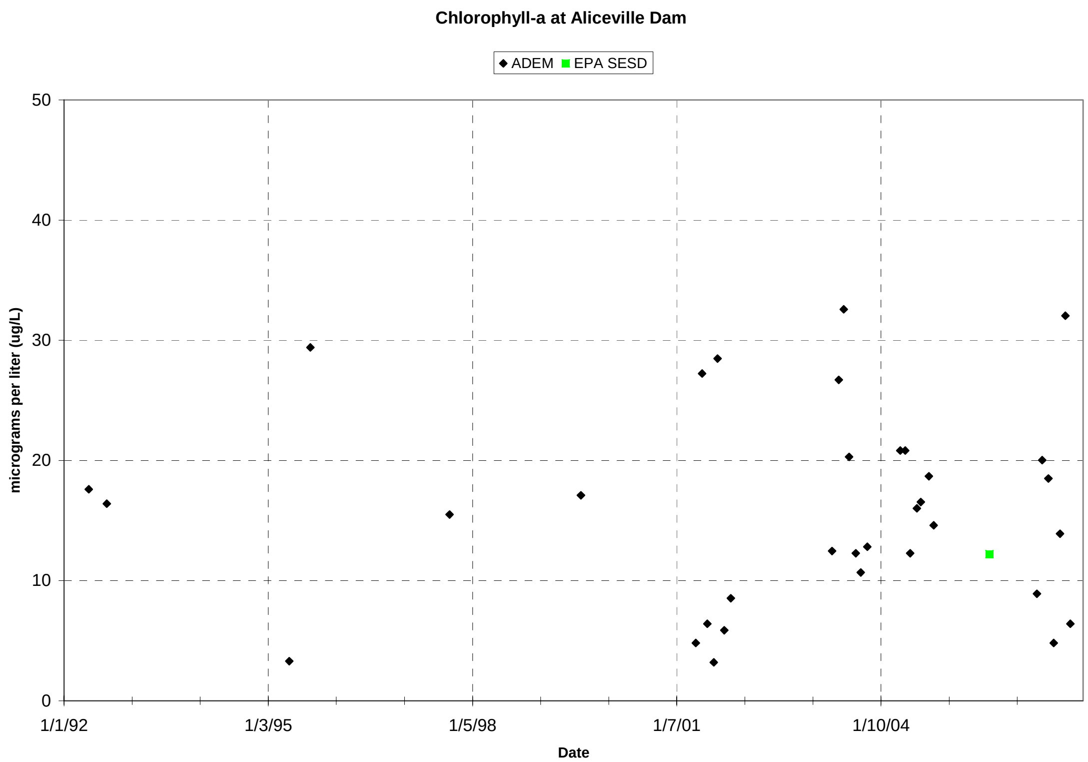


Figure 15: Chlorophyll-a at Aliceville Dam

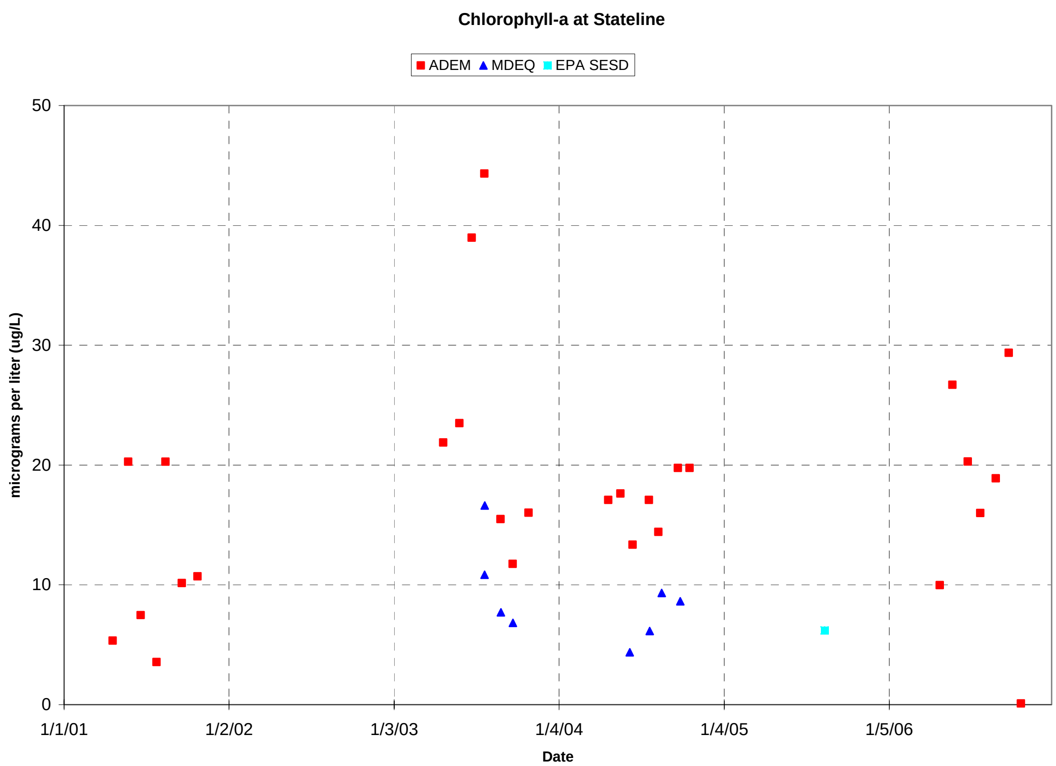


Figure 16: Chlorophyll-a at stateline

In addition to the long-term BOD tests, in-situ water quality measurements and water column profile data presented above, the EPA field study included dissolved oxygen diffusion and reaeration measurements, diurnal DO measurements, velocity measurements, flow measurements, time of travel, and sediment oxygen demand measurements. More details and discussion of the results for this effort is described in the report, “Tennessee-Tombigbee Waterway Water Quality Study, Columbus, Mississippi” (USEPA. 2006.). For this TMDL development project EPA performed additional non-linear analysis on the long term BOD tests to determine the best decay rates. This analysis which involved utilizing the Long Term BOD Analysis Program (3.0) developed by the Georgia Environmental Protection Division (GAEPD 2004) is presented in Appendix A.

4 Other Available Data

Additional data sources were used to set-up the models. Sources included USGS topographic maps, the National Hydrography Dataset (NHD) area and waterbody GIS coverages, and US Army Corps of Engineers shoreline coverages to define the model surface area and lay out the model grid. Bathymetry for the Tombigbee River and Aliceville Reservoir collected by the US Army Corps of Engineers and ADEM was used to define channel geometry for the reservoir. Hourly flows from USGS gages downstream of Stennis Lock and Dam (USGS 02441390) and Bevill Lock and Dam (USGS 02444160), and daily flow for Luxapallila Creek (USGS 2443500) were used to drive the hydraulics of the system. Surface water elevation of the Aliceville pool from the US Army Corps of Engineers was used to calibrate the EFDC model and correct the flows. US Army Corps of Engineers storage volume to elevation tables for Aliceville Reservoir were also used to make sure the model represented this relationship.

EFDC and WASP require climate data that includes air temperature, relative humidity, precipitation, barometric pressure, solar radiation and cloud cover. Climate data from the Golden Triangle Regional Airport (WBAN 53893) station near Columbus, MS was used in the models.

5 Biology information was also considered in the development of the Aliceville TMDL.

EPA noted that during the 2005 Aliceville field study, aquatic plants had been a problem and that the US Army Corps of Engineers had applied herbicides to control these plants. The USGS maintains a list of exotic invasive aquatic plant populations, and Aliceville Reservoir and the Tombigbee River are listed as having an established population of hydrilla verticillata in 1997 (http://nas.er.usgs.gov/queries/collectioninfo.asp?SpeciesID=6). Another USGS web site describes the range of hydrilla as less common throughout Alabama, although widespread in the Mobile Delta and northern portion of the Mobile Bay; common at Coffeeville, Aliceville and Oak Mountain reservoirs of central Alabama, and well established at Guntersville, and other northern impoundments on the Tennessee River. Extending along the Tombigbee River from Aliceville Reservoir, AL into eastern Mississippi. (http://nas.er.usgs.gov/taxgroup/plants/docs/hy_verti.html). Figure 17 shows a photograph of a hydrilla mat in Aliceville provided by Alabama Division of Wildlife and Freshwater Fisheries and Jerry Moss, copied from http://www.outdooralabama.com/fishing/freshwater/where/reservoirs/aliceville/pix/.

Figure 17: Hydrilla mat in Aliceville Reservoir (Provided by Alabama Division of Wildlife and Freshwater Fisheries and Jerry Moss to http://www.outdooralabama.com/fishing/freshwater/where/reservoirs/aliceville/pix/.).

Figure 18: Water hyacinth on Aliceville reservoir.

Figure 19: Water hyacinth on Aliceville reservoir.

Figure 18 and Figure 19, provided by the USACOE, show water hyacinth covering the water in Aliceville Lock and Dam in late 2004 and 2005. Hydrilla, water hyacinth and bulrush are becoming increasingly problematic. Navigation has been impeded due to their proliferation. The U.S. Army Corp of Engineers (USACOE) has utilized aerial and boat spraying of herbicides to control the plant growth.

According to the Corps of Engineers, plant species that have been controlled include water hyacinth (Eichornia crassipes), cuban bullrush (Scirpus cubensis), hydrilla (Hydrilla verticulata), Eurasian milfoil (Myriophyllum spicatum), and American lotus (Nelumbo lutea). Noxious aquatic plant growth is a seasonal problem (May - October) and is primarily associated with the abundant acreage of shallow water embayments of numerous feeder creeks and streams that provide ideal growing conditions for many of the listed problem species. Herbicide applications are typically applied June-October annually. In the past, Aliceville Pool has required as many as 10-12 applications annually with daily applications ranging from 20 - 300 acres. Invasive aquatic plants that have the capability to adversely impact project purposes are targeted very early during the growing season in an attempt to minimize applications and increase cost effectiveness of treatment. The USACOE had significant problems with particularly water hyacinth in late 2004 and 2005 (see Figure 18 and Figure 19).

While the exact effects of the plant growth and subsequent spraying upon water quality within the system are unknown, this water body certainly receives excess nutrients. We know that hydrilla and water hyacinth can uptake nutrients from the water column. Therefore, it is likely that these plants are using the available forms of nitrogen and phosphorus which keeps the nutrient levels measured in the water column relatively low. It is also possible that algae and chlorophyll-a would increase in the reservoir if the current loading of nutrients continues and these undesirable macrophytes are eradicated or controlled to low populations. This potential problem may be avoided by developing nutrient targets and reducing the nutrient loads delivered to this reservoir. Since some of these noxious macrophytes can also obtain nutrients from the substrate, there is no guarantee that they can by controlled by nutrient reductions alone. However, the potential for excess algae exists and EPA recommends that nutrient loading to the Tombigbee waterway and Aliceville reservoir be studied further. This TMDL addresses the oxygen dynamics based on the currently available data. The presence of noxious plants indicates a possible nutrient enrichment problem. The models developed and used for this DO TMDL can be used to evaluate excessive nutrient scenarios, and they may be helpful in developing nutrient targets.

6 Modeling Approach

A set of mathematical models were used to estimate unmeasured loads, relate the known and estimated loads to target concentrations, and evaluate various load reduction strategies. These included a hydrodynamic model, a watershed loading model, and an eutrophication, water quality model. The models extend from Columbus Dam (Stennis Lock and Dam) downstream to Aliceville Dam (Bevill Lock and Dam). Flows and water quality loads enter the model boundaries at Columbus Dam, Luxapallila Creek, Cedar Creek, Coalfire Creek, Broken Pumpkin Creek, Ellis Creek, Gilmer Creek, Kincaide Creek, James Creek and the point sources Sanderson, Eka Chemical, Weyerhaeuser, and the City of Columbus WWTP. The Columbus Dam model boundary and the Luxapallila Creek boundary include the loads from the distant point sources discussed in Section 2.

6.1 Environmental Fluid Dynamics Code (EFDC) was used to model three dimensional hydrodynamics for Aliceville reservoir.

The hydrodynamic model was configured as 113 grid cells to accurately represent the Aliceville Reservoir and Tombigbee River system. The cell size varies, but each is approximately 760 meters long (half a mile) and 280 meters wide with an average area of 170,000 square meters. The model cells are shown in Figure 20. Each segment was subdivided into one to five vertical layers based on the normal depth. So deeper pools are divided into 5 layers and shallow river segments are represented as a single layer. The EFDC model is used to simulate the dynamic flow and water temperature from Stennis Lock and Dam to Bevill Lock and Dam, and write this information to a WASP hydrodynamic input file. More details about the development of this EFDC model of Aliceville Reservoir can be found in Appendix B in the report “Tombigbee River and Aliceville Reservoir: Three Dimensional Hydrodynamic Modeling Report” (Tetra Tech. 2007.). The report in Appendix covers the initial setup and calibration of the Aliceville reservoir EFDC model for Jan. 2003 through Sept. 2005. For this TMDL the EFDC model was expanded to include the period to Sept. 2006.

Through the hydrodynamic linkage file the two models are linked and WASP computes the water quality for each layer of each EFDC cell. EFDC and WASP were setup for about 32 miles of the Tombigbee Waterway from Stennis Lock and Dam in Columbus, MS to the Aliceville Reservoir Pool impounded by Bevill Lock and Dam, in Pickens, AL. The eutrophication module of WASP is then used to simulate dissolved oxygen, nutrients, BOD and phytoplankton. The models were setup to simulate the conditions from Jan. 2003 to Sept. 2006. This period represents the current pollutant loads discharged from point and non-point sources. It also includes periods of wet, normal and dry precipitation patterns, that influence dissolved oxygen dynamics. Figure 21 is a plot of twenty-five years of flow at Stennis Lock and Dam, and shows that 2003 and 2005 water years were more wet than normal and 2006 was more dry than normal.

6.2 The Water Quality Analysis Simulation Program (WASP) model was setup to evaluate the effect of BOD, nutrients, algae, and other oxygen demanding substances on DO processes.

The Water Quality Analysis Simulation Program version 7.2 (WASP7) is an enhancement of the original WASP. This model helps users interpret and predict water quality responses to natural phenomena and man-made pollution for various pollution management decisions. WASP7 is a dynamic compartment-modeling program for aquatic systems, including both the water column and the underlying benthos. The time-varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange are represented in the basic program (USEPA. 2001).

Water quality processes are represented in special kinetic subroutines that are either chosen from a library or written by the user. WASP is structured to permit easy substitution of kinetic subroutines into the overall package to form problem-specific models. WASP7 comes with two such models -- TOXI for toxicants and EUTRO for conventional water quality. Earlier versions of WASP have been used to examine eutrophication of Tampa Bay; phosphorus loading to Lake Okeechobee; eutrophication of the Neuse River and estuary; eutrophication and PCB pollution of the Great Lakes, eutrophication of the Potomac Estuary, kepone pollution of the James River Estuary, volatile organic pollution of the Delaware Estuary, and heavy metal pollution of the Deep River, North Carolina (USEPA. 2001). In addition to these, numerous applications are listed in Di Toro et al., 1983.

The flexibility afforded by the Water Quality Analysis Simulation Program is unique. WASP7 permits the modeler to structure one, two, and three-dimensional models; allows the specification of time-variable exchange coefficients, advective flows, waste loads and water quality boundary conditions. The eutrophication module of WASP7 was applied in the development of these TMDLs.

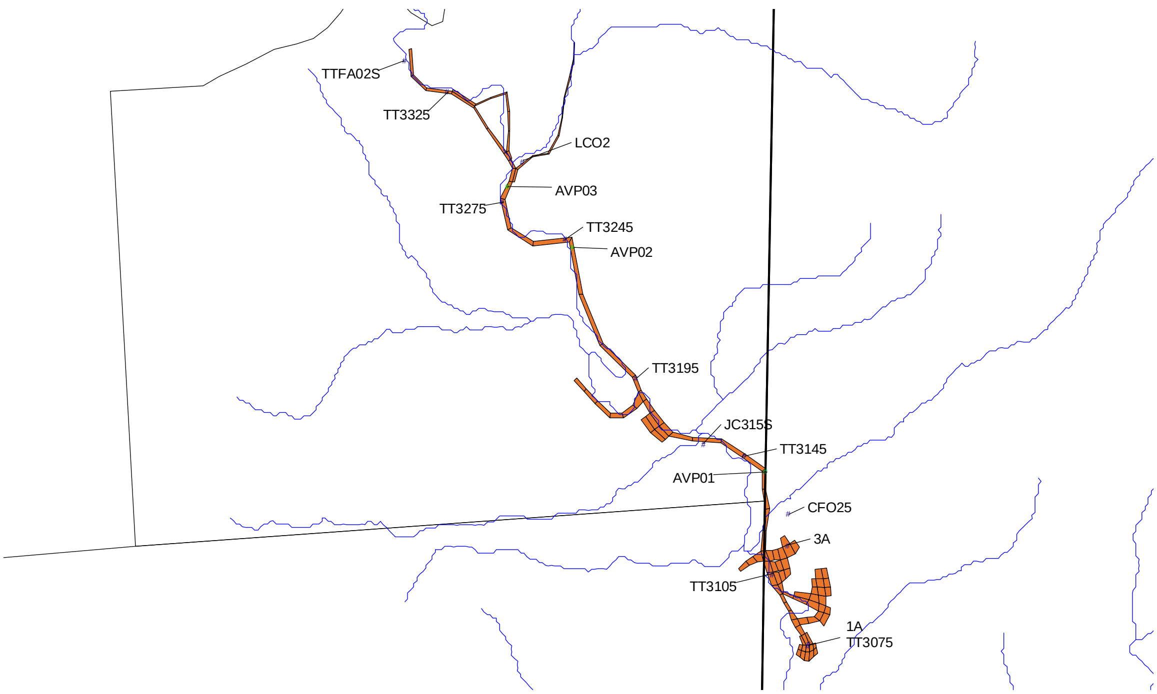


Figure 20: Model of Aliceville Reservoir showing water quality monitoring stations

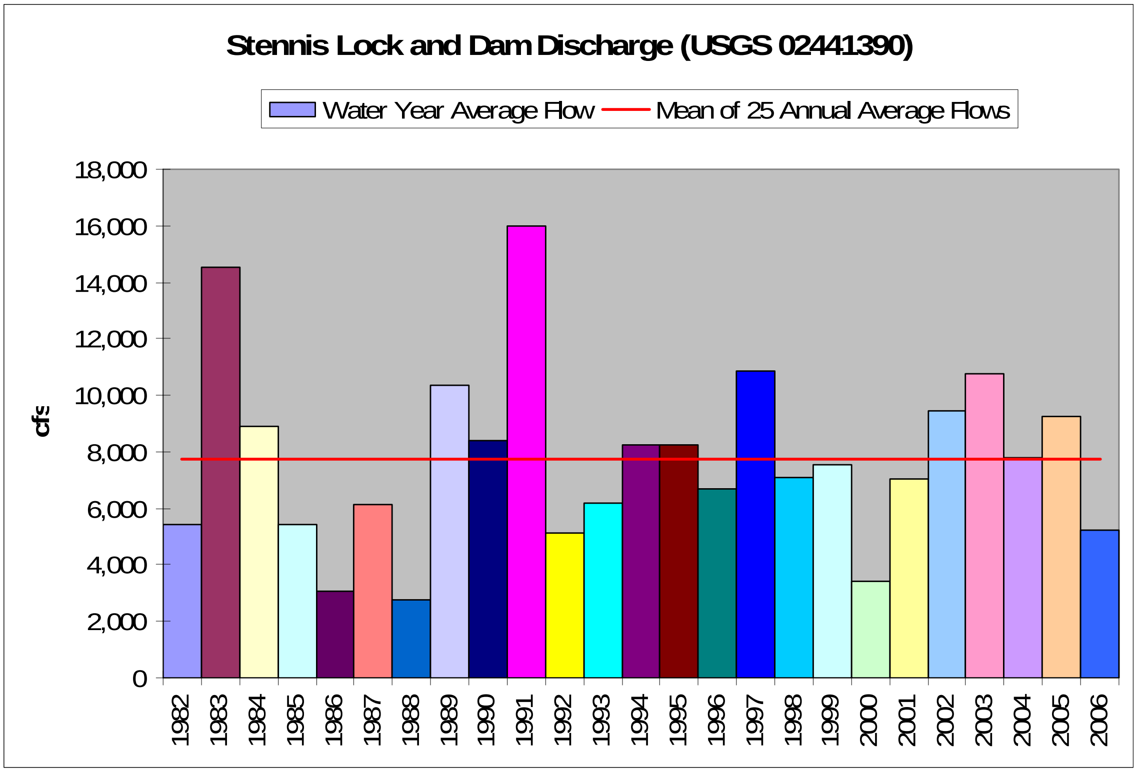


Figure 21: Discharge at Stennis Lock and Dam

6.3 Tributary flow estimation

Between Stennis Lock and Dam near Columbus, MS and Bevill Lock and Dam a total of 1350 square miles of watershed area drain into the Aliceville reservoir. Daily flow recorded at USGS gage 02443500 on the Luxapallila near Columbus with a drainage area of 715 square miles was input to EFDC to represent the Luxapallila Creek flow and to estimate the remaining tributary flow. The flow for each tributary was estimated by drainage area ratio to the Luxapallila drainage area. The flow was estimated and applied for eight major tribitaries; Cedar Creek, Coal Fire Creek, Broken Pumpkin Creek, Ellis Creek, Gilmer Creek, Magowah Creek, Kincaid Creek, and James Creek. These estimates were input to the EFDC model for the simulation period of Jan. 2003 through Aug. 2006.

6.4 Watershed Loading

The non-point source water quality loading from the tributaries was estimated with BASINS PLOAD. Estimated BOD, nitrogen, and phosphorus loads for this section of the Tombigbee River downstream of Stennis Dam at Columbus are shown in Table 8. These were calculated by the EPA Simple method formula shown in Table 9 from the BASINS 4.0 PLOAD model (EPA, 2001). The TN loads were divided into nitrate plus nitrite, ammonia, and organic nitrogen fractions according to measured data. These fractions are 0.03, 0.14, 0.83 for nitrate plus nitrite, ammonia, and organic nitrogen, respectively. The TP load was divided into 0.8 for dissolved organic phosphorus and 0.2 for dissolved ortho-phosphate based on available data. The BOD load was expressed as CBODu in the water quality model by multiplying by an f-ratio, which is the ratio of ultimate BOD to 5-day BOD of 2.35. Since these are non-point sources which are transported by storm-water runoff, these loads were applied so they vary with the river flow. That is the annual load was multiplied by the daily flow and divided by the average daily flow of the simulation period. Landuse was based on the BASINS NLCD 1999 land use and land cover features and acreage shown in Table 7. Landuse of the watersheds upstream of Stennis Lock and Dam is shown in The watersheds upstream of Aliceville Reservoir are shown in Figure 1. Landuse of the watersheds is shown in **Table 1. The landuse of the** Aliceville watersheds is predominantly agriculture, forest and wetlands.

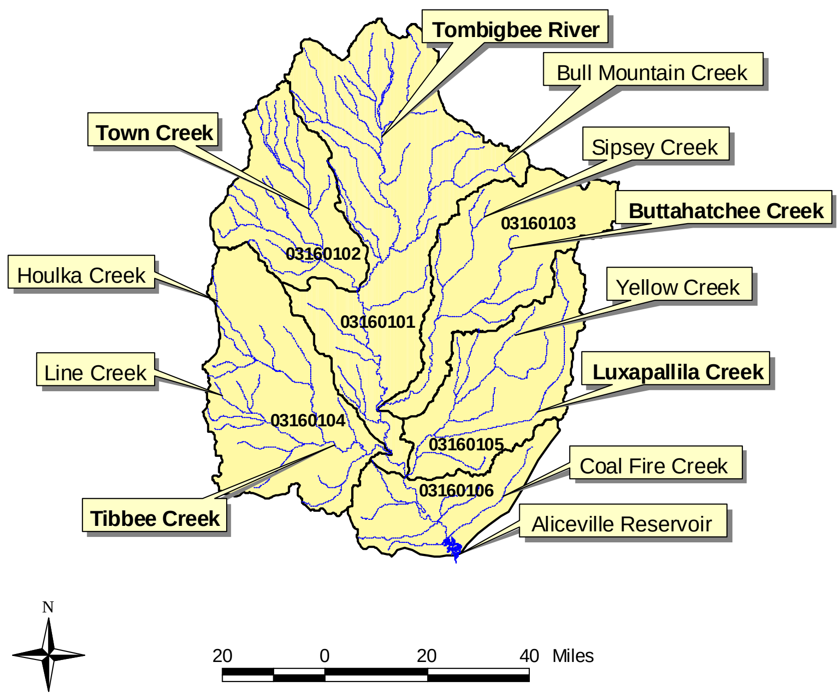


Figure 1: Watersheds **Upstream of Aliceville Reservoir**

Table 1. The landuse of the upstream watersheds and the Aliceville Reservoir watersheds is predominantly agriculture, forest and wetlands.

Table 6: Tributaries to Aliceville Reservoir

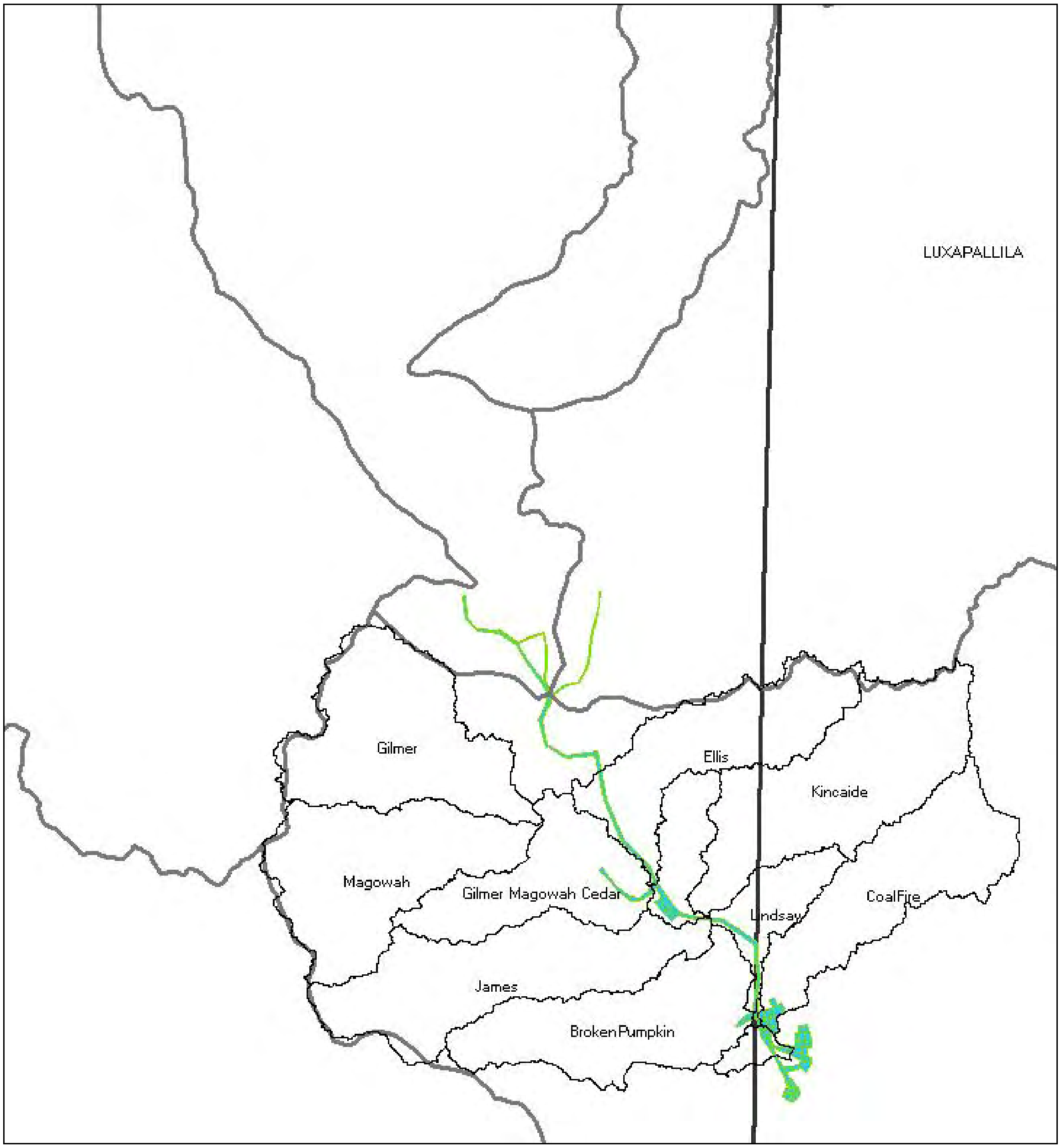


Table 7: NLCD Landuse in Acres for Tributaries to Aliceville Reservoir.

	Gilmer	Ellis	Kincaide	Coal Fire	Unnamed	Cedar	Magowah	Lindsay	James	Broken Pumpkin
Agriculture – Cropland	12922	2914	2501	1150	1013	7046	15362	640	19192	10647
Agriculture - Pasture	7814	2005	1492	967	672	1721	7286	322	3682	6579
Barren or Mining	13	150	0	0	0	53	190	0	0	0
Forest	6712	14131	24553	18467	1364	4506	4524	3974	3310	1350
Transitional	0	68	978	306	10	3	0	226	0	2
Urban	392	132	182	33	9	63	52	8	21	8
Water/Wetlands	2540	3982	3526	4558	4422	5989	2071	2827	4113	6905

Table 8: Estimated Non-point Source Loads in the Tombigbee River Watershed from Stennis Dam to Bevill Dam

Parameter	Total Load in lbs/year and (lbs/day)	Luxapallila	Gilmer	Ellis	Kincaide	CoalFire	Cedar and Magowah	James	BrokenPumpkin
BOD	2703479 (7404)	1948445	140412	80824	139922	76259	154359	89479	73779
TN	504421 (1381)	360443	24438	15269	26836	15106	29939	17699	14690
TP	105223 (288)	75634	5253	3153	5537	3050	6092	3560	2945

Table 9: Pollutant Load Equation from EPA BASINS PLOAD users manual

$LP = \Sigma\, u\, (P * PJ * RVu * Cu * Au * 2.72 / 12)$
Where: LP = Pollutant load, lbs
P = Precipitation, inches/year
PJ = Ratio of storms producing runoff (default = 0.9)
RVu= Runoff Coefficient for land use type u, inches of runoff/inches of rain
Cu = Event Mean Concentration for land use type u, milligrams/liter
AU = Area of land use type u, acres

6.5 Point Source Loading

Loads for the point source facilities Sanderson, Eka Chemical, Weyerhaeuser, and the City of Columbus WWTF are input to the water quality model and flows were input to the hydrodynamic model. These point source loads were entered as time varying concentrations in mg/L or as time varying loads in kg/day. The water quality at Columbus Dam represents the model boundary water quality load at the upstream dam. This load was entered as time varying concentrations or a constant concentration depending on the available data for each constituent. The water quality load is comprised of non-point source loads and point source loads as measured at or near the Columbus Dam. The fraction of this boundary load that is from point sources was estimated as described in Section 2. Additionally, the Luxapallila Creek load includes a distant point source facility load. Like the Columbus Dam boundary load, the Luxapallila total load that includes both point source loads and non-point source loads was entered into the model at the boundary. Also, the fraction of the load from the point source was estimated as described in Section 2.

7 Model Sensitivity Analysis

To better understand the hydrodynamic and water quality models, sensitivity tests were performed on dam release depth, reaeration rate, sediment oxygen demand rate, and BOD decay rate.

7.1 Reservoir Operations

Releases from the lake surface create different dynamics than releases from the lake bottom. Bevill Lock and Dam can release from the surface, middle and the bottom. The dam has a fixed crest weir section that releases continuously from the surface. There is also a gated section that releases from the bottom when open slightly and releases from the bottom, middle, and surface when fully open. In addition Bevill Lock and Dam releases through a valve near the reservoir bottom to fill the lock. This flow depends on the number of lockages which varies depending on recreational and commercial traffic. Based on this information the sensitivity of the model to different release locations was explored. A scenario with releases from the top two model layers (50% from layer 5 and 50% from layer 4) was compared with a scenario with releases from the top and bottom (30% from the model surface layer 5 and 70% from model layer 2). Figure 22 shows the DO at station 1A for both scenarios. There is a noticeable difference due to the bottom mixing that occurs with bottom releases that prevent as much DO stratification. The model with releases from the top layers only, predicted a minimum DO of about 4.0 mg/L in Aug. 2003 and Sept. 2005, while the model with top and bottom releases predicted a minimum DO of 4.45 mg/L in July 2003 and 4.3 mg/L in Sept. 2005. During very low inflow conditions the gates are closed and the primary release flows over the weir from the surface layers of the reservoir. This allows the DO to stratify and magnifies the low DO in the reservoir surface once mixing occurs. This causes very little waste assimilation capacity during such low flow conditions.

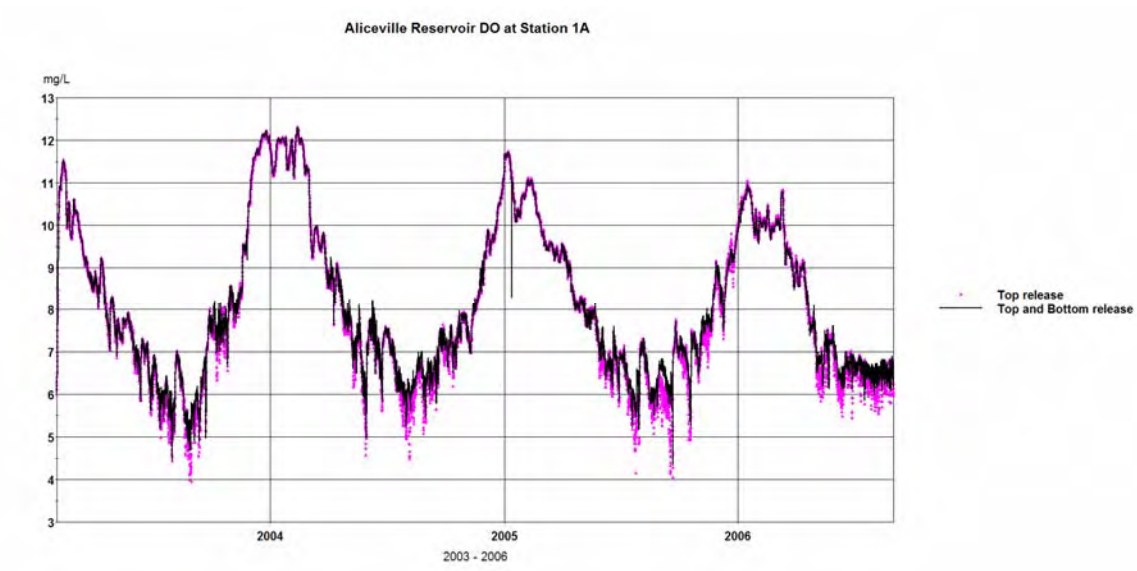


Figure 22: Release from Top versus Release from Top and Bottom Layers of Aliceville Reservoir.

7.2 Reaeration

In the water quality model the O'Connor-Dobbins formula was used to compute flow-induced reaeration and the O'Connor formula was used to compute the wind-induced reaeration. This formula estimated that reaeration rates were proportional to depth-average velocity and inversely proportional to total depth. Application of this formula to the surface layer only introduces uncertainty to the model. Therefore a sensitivity test was performed to demonstrate model difference due to varying the reaeration rate. A scenario with reaeration computed with the O'Conner-Dobbins formula was compared to a scenario with twice this rate. The DO at station 1A near the Aliceville Dam pool with the single reaeration rate formula scenario and the doubled rate scenario are shown in Figure 23. The lowest DO in the simulation period occurred Aug. 29, 2003 and Sept. 21, 2005. In Aug. 2003 the DO was 4.16 under the formula rate scenario (1X rate), while the DO at this time was 4.6 mg/L with the rate doubled. In Sept. 2005 the DO under the formula rate was 4.06 mg/L, and the DO concentration was 4.7 with the rate doubled. The single formula reaeration rate compares well to the lowest of the field measurements and the doubled rate compares well to the highest measurements.

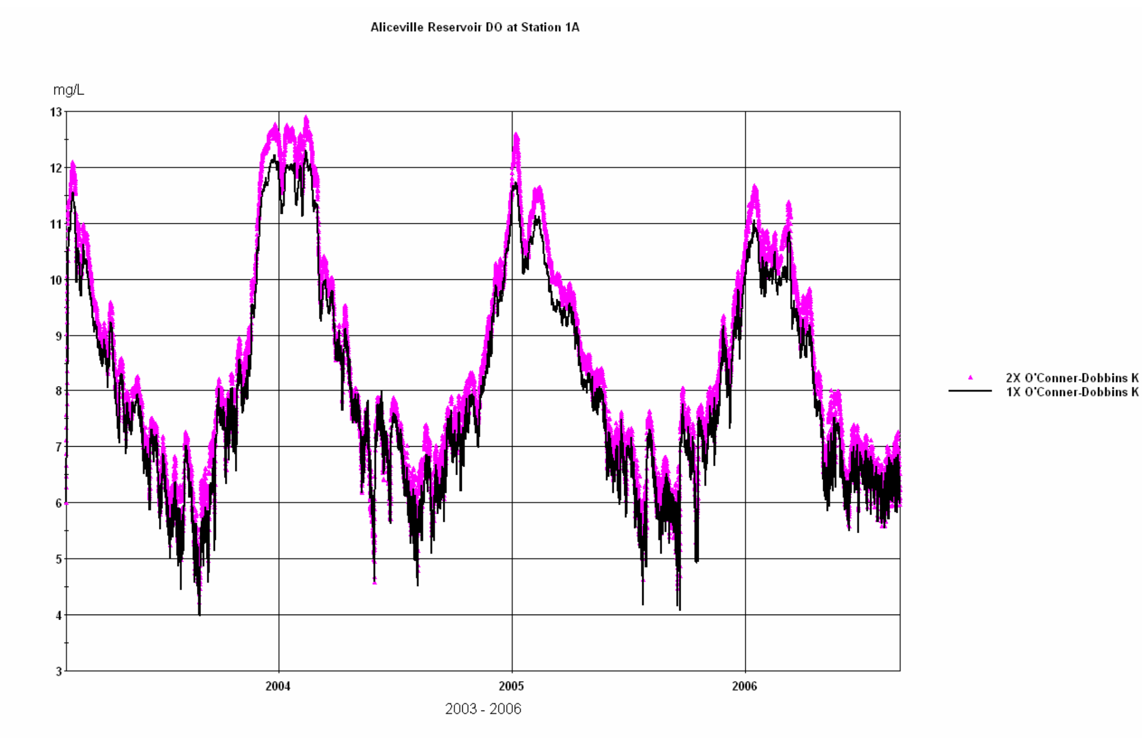


Figure 23: DO at Station 1A with the reaeration rate calculated by the O'Conner-Dobbins formula (1X rate) and the rate doubled (2X rate).

7.3 SOD Rate

To explore the model sensitivity to SOD rate two scenarios were compared. A scenario with SOD at the calibrated rate was compared to a scenario with no SOD. The DO at station 1A for both scenarios is shown in Figure 24. The minimum DO predicted by the model with SOD is 4.45 mg/L and the minimum DO predicted by the model without SOD is 4.89 mg/L, which is 0.44 mg/L higher.

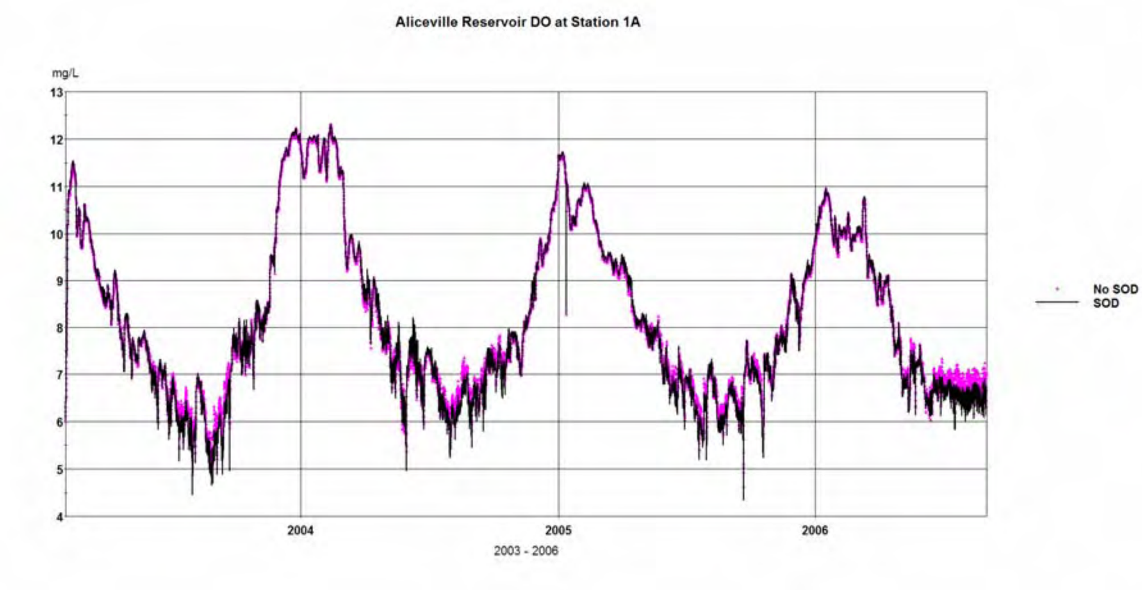


Figure 24: DO at Station 1A with SOD and without SOD.

7.4 CBOD Decay Rate

To understand model sensitivity to the BOD decay rate, a model simulation was run with a single BOD decay rate of 0.06 per day for all BOD loads. A comparison of the CBOD between the 3 rates model and this single rate model at the Aliceville Reservoir station 1A is shown in Figure 25 and Figure 26. A comparison of the resulting DO for these two simulations is shown in Figure 27 and Figure 28. The difference between the two models in CBOD is noticeable and as much as 1 mg/L lower in the 3 rates model. The largest difference in DO concentrations is 0.36 mg/L (May 22, 2004). During the critical low DO period of Aug. 28, 2003 the DO was 0.14 mg/L higher in the 3 rates model, and during the critical Sept. 17, 2005 period the DO was 0.1 mg/L higher in the 3 rates model.

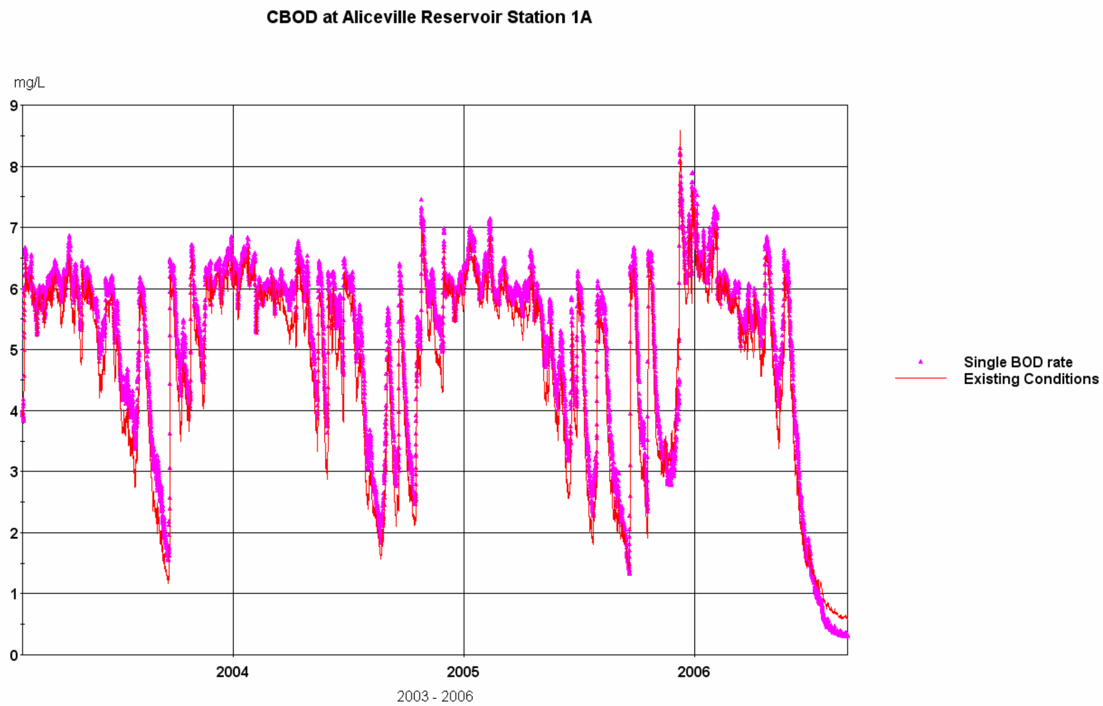


Figure 25: Comparison of CBOD under 2 simulations; (1) three BOD decay rates and (2) one rate.

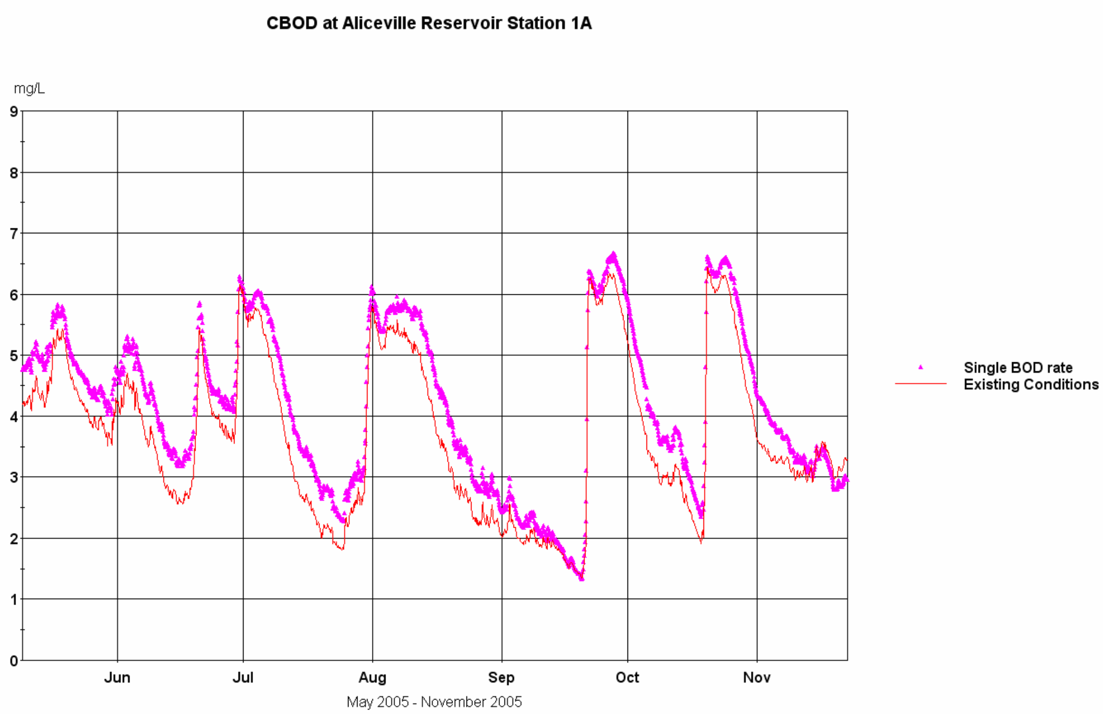


Figure 26: Summer 2005 Comparison of CBOD under 2 simulations; (1) three BOD decay rates and (2) one rate.

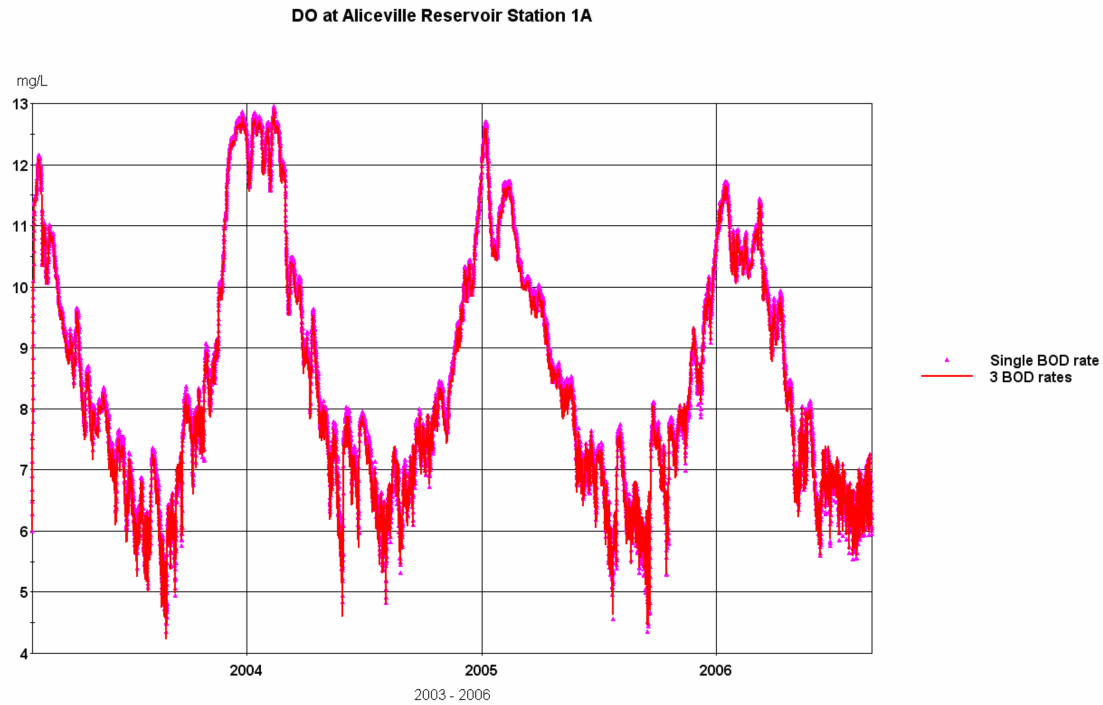


Figure 27: Comparison of DO under 2 simulations; (1) three BOD decay rates and (2) one rate.

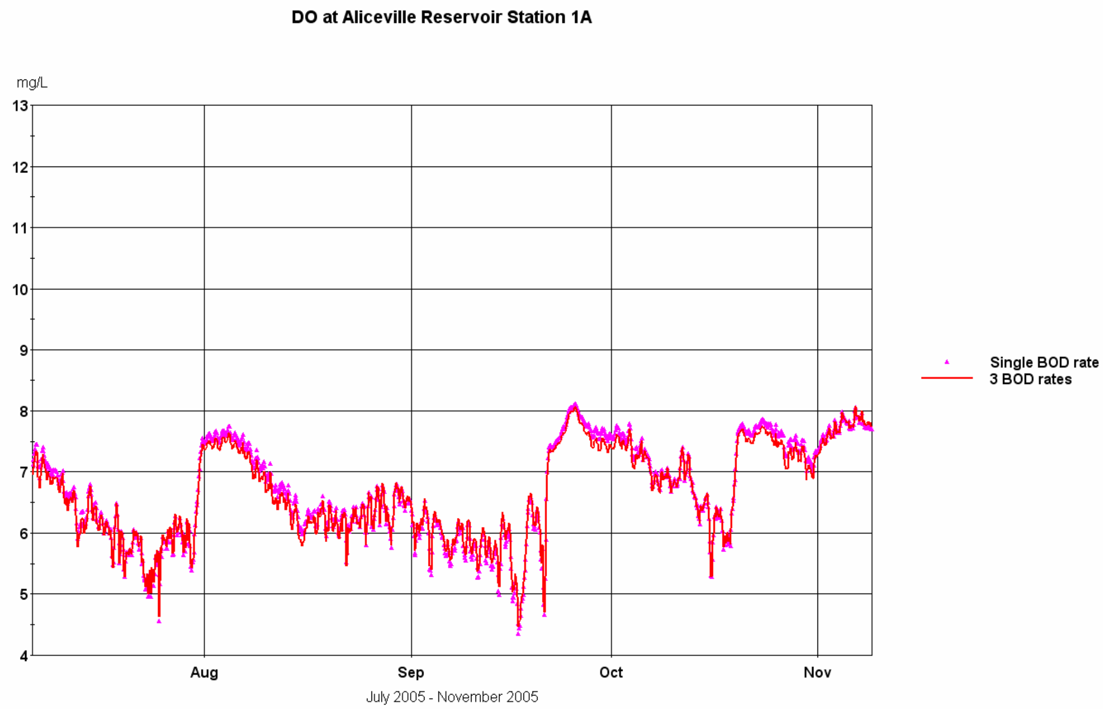


Figure 28: Summer 2005 Comparison of DO under 2 simulations; (1) three BOD decay rates and (2) one rate.

8 Model Configuration, Calibration, and Validation

The EFDC model was initially configured and calibrated to 2003 through Oct. 2005 conditions. This model configuration and calibration is documented in Appendix B. This model was then applied to the low flow conditions of 2006 which served to further validate that the model is able to simulate a wide range of conditions. The WASP model was calibrated to 2003 through 2006 conditions.

8.1 Dissolved Oxygen, Reaeration, and Sediment Oxygen Demand

Figure 30 through Figure 34 show predicted and observed five foot depth DO at the state line. Figure 35 through Figure 37 show the five foot depth DO at Aliceville Dam forebay. Figure 40 shows the predicted DO at the lake surface and bottom layers match the observed DO. In general the predicted DO matches the seasonal trend and magnitude of the observed DO well. However, there are times such as during the ADEM August 2006 diurnal monitoring period that the predicted DO is too high. At other times, such as the surface layer during the EPA-SESD 2005 water quality study, the predicted DO was too low. These instances of high and low predictions are due to limitations of available data such as tributary and upstream boundary DO. Tributary dissolved oxygen was estimated from temperature data for Luxapallila Creek and assuming 80 percent saturation. Similarly, the DO was estimated at Stennis Dam, which is the upstream boundary, from temperature data at the Weyerhaeuser Columbus Mill intake near river mile 327 in Aliceville reservoir and assuming 90 percent saturation. A higher percent of saturation is used here because the release of water through the lock creates turbulence that promotes reaeration.

Diffusion measurements were conducted by EPA's SESD and reaeration rates were calculated from these measurements. The reaeration rates ranged from 0.2 to 0.74 per day. The results are presented in the Tennessee-Tombigbee Waterway Water Quality Study report. In the water quality model the O'Connor-Dobbins formula was used to compute flow-induced reaeration and the O'Connor formula was used to compute the wind-induced reaeration. The measured rates and the predicted rates are shown in Figure 29. To compare the measured rates, which are average reaeration rates over the depth of the whole water column, to predicted rates for the surface layer, the predicted rates were multiplied by the ratio of model layer depth to reservoir depth. The water quality model computes reaeration rates for the surface model layer only. The oxygen that enters this surface layer through diffusion is then mixed vertically with the lower layers of the water column by the model's hydrodynamic equations.

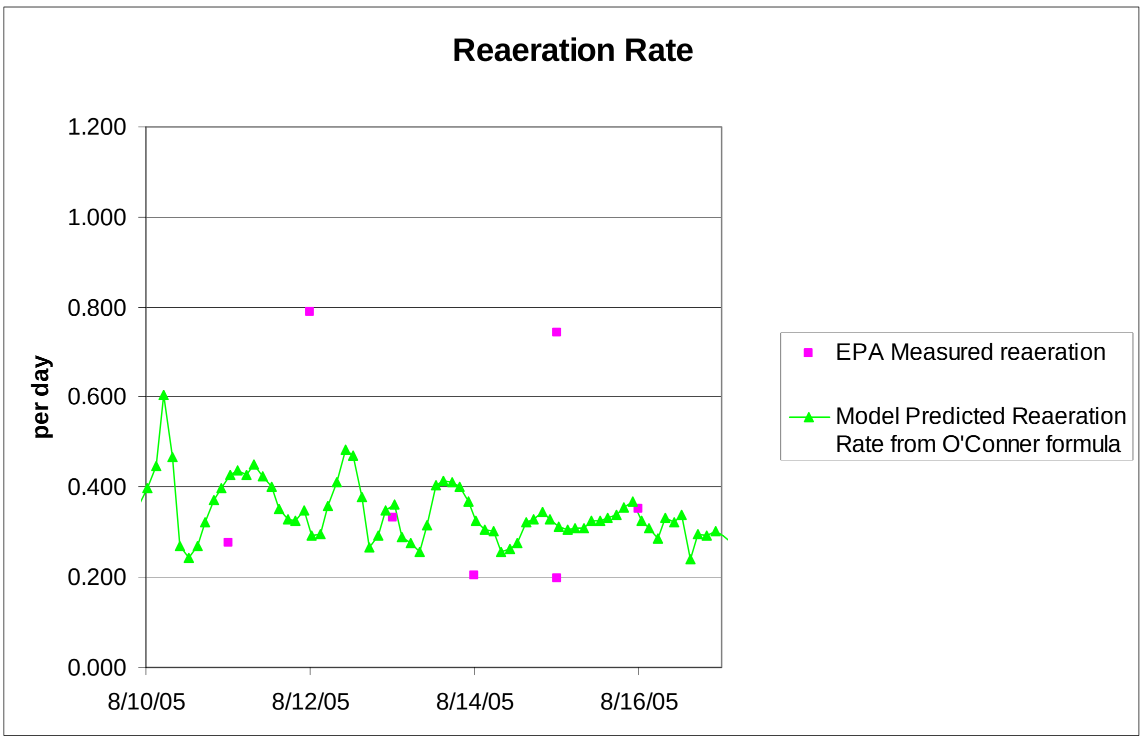


Figure 29: Flow-induced reaeration rates; measured and instantaneous and daily average predicted.

Sediment oxygen demand rates were also measured in the EPA water quality study. Rates ranged from 0.53 to 1.44 grams oxygen per square meter per day or 0.38 to 0.88 corrected to 20 degrees Celsius. These rates were input to the water quality model initially, and then adjusted to reflect observed DO in the lower layer of the reservoir. Figure 38 and Figure 39 show the predicted DO and the observed DO in the bottom layer of the reservoir. The SOD rates were decreased from the measured rates so the predicted DO in the bottom layer matched the observed DO. Although, EPA believes the measured rates are correct, they only represent a small area of the reservoir benthos. Each SOD chamber has a volume of 64.5 liters and covers a surface area of 0.27 square meters. The measured rates are applied to the reservoir bottom sediment which covers a much larger heterogeneous area. So, it is reasonable to adjust these rates with respect to the measured water column DO. Another reason for adjusting the rates downward is the rates are affected by the DO level in the water column, and as the DO decreases the SOD rate is expected to decrease. The model treats the rate as a constant, regardless of the DO level. Therefore, the model may overestimate the consumption of DO due to SOD. In this Aliceville model the modeled rates were adjusted downward to one half the measured rates.

8.2 Nitrogen and Phosphorus

Figure 41 through Figure 44 shows that predicted and observed ammonia, organic nitrogen, and nitrate plus nitrite. Each form of nitrogen is predicted relatively well compared to the observed concentrations at Aliceville dam. The nitrification rate was determined from the long term BOD test and non-linear analysis. These long-term test results are shown in Appendix A: Long-term BOD Analysis. The nitrification and denitrification rates are shown in Table 10. Where data was not available for the specific form of nitrogen it was estimated from the total nitrogen according to measured data. These fractions are 0.03, 0.14, 0.83 for nitrate plus nitrite, ammonia, and organic nitrogen, respectively.

Similarly, the TP load was divided into 0.8 for dissolved organic phosphorus and 0.2 for dissolved ortho-phosphate when data for each was not available. Figure 46 shows dissolved inorganic phosphorus at Aliceville dam, Figure 47 shows organic phosphorus at Aliceville dam, and Figure 48 shows total phosphorus at Aliceville dam. These predicted phosphorus concentrations match the observed data very well.

8.3 Carbonaceous Biochemical Oxygen Demand

Figure 45 shows the plotted calibration results of CBOD at Aliceville. There was no measured BOD data for 2003 or 2004 and only the EPA results were available for 2005, so CBOD was estimated from the relationship between total organic carbon and CBOD for comparison purposes. The predicted BOD is somewhat lower than these estimated CBOD with the predicted CBOD ranging from about 2 to 6, and the estimated CBOD ranging from about 5 to 14. In 2006 ADEM measured 5-day CBOD. An ultimate CBOD to 5-day CBOD f-ratio of 3.43 from a first order analysis of the EPA sample at station TT307 was applied to these 5-day CBOD data to estimate ultimate CBOD. These estimates ranged from 2.5 to 12.

Three BOD decay terms were utilized in the water quality model, a fast and a slow rate for all discharges except Weyerhaeuser Paper Mill. A rate of 0.024 per day as shown in Figure 67 was used for the Weyerhaeuser BOD effluent. The non-linear analysis of the long term BOD test revealed that a two-term BOD rate best fit the data for all of the reservoir BOD samples. These reservoir results are shown in Figure 55 through Figure 65 of Appendix A. The BOD, excluding the Weyerhaeuser Paper Mill effluent, was divided into fast and slow components to represent the mixed BOD in the reservoir best. A fast BOD rate of 0.11 was used for 58 percent of the BOD load, and a slow rate of 0.045 was used for 42 percent of the BOD load. Part of the difference of the predicted from the estimated CBOD can be explained by lack of trend data for BOD. In the model the single long term measurement of BOD was used at the upstream boundary at Stennis Lock and Dam for the whole simulation period. Since 84 percent of the CBOD load is from sources upstream of Stennis Dam (see Figure 3), this measured value was considered the best available information and no adjustments were made to the BOD.

8.4 Phytoplankton

The water quality model adjusts the growth rate for algae throughout the simulation for ambient temperature, light, and nutrient conditions. The water quality model follows Monod growth kinetics with respect to the important nutrients, nitrogen and phosphorus. That is, at an adequate level of substrate concentration, the growth rate proceeds at the saturated rate for the ambient temperature and light conditions present. At low substrate concentration, however, the growth rate becomes linearly proportional to substrate concentration. Thus, for a nutrient with concentration Nj in the jth segment, the factor by which the saturated growth rate is reduced is: Nj/(Km + Nj). The constant, Km (called the Michaelis or half-saturation constant) is the nutrient concentration at which the growth rate is half the saturated growth rate. Because there are two nutrients, nitrogen and phosphorus, considered in this framework, the Michaelis-Menten expression is evaluated for the dissolved inorganic forms of both nutrients and the minimum value is chosen to reduce the saturated growth rate. These phytoplankton rates are shown in Table 10. Figure 49 shows the predicted and observed algae in terms of chlorophyll-a at station 1A. The model predicts the chlorophyll-a well except for the peaks which surpass 30 ug/L in 2003.

Table 10: WASP Environmental and Chemical Constants

Nitrification Rate Constant @20 °C (per day)	0.16
Nitrification Temperature Coefficient	1.047
Half Saturation Constant for Nitrification Oxygen Limit (mg O/L)	2
Denitrification Rate Constant @20 °C (per day) actor	0.03
Denitrification Temperature Coefficient	1.045
Half Saturation Constant for Denitrification Oxygen Limit (mg O/L)	0.1
Dissolved Organic Nitrogen Mineralization Rate Constant @20 °C (per day)	0.04
Dissolved Organic Nitrogen Mineralization Temperature Coefficient	1.047
Organic Nitrogen Decay Rate Constant in Sediments @20 °C (per day)	0.03
Organic Nitrogen Decay in Sediment Temperature Coefficient	1.07
Fraction of Phytoplankton Death Recycled to Organic Nitrogen	0.5
Mineralization Rate Constant for Dissolved Organic P @20 °C (per day)	0.01
Dissolved Organic Phosphorus Mineralization Temperature Coefficient	1.047
Organic Phosphorus Decay Rate Constant in Sediments @20 °C (per day)	0.001
Organic Phosphorus Decay in Sediments Temperature Coefficient	1.047
Fraction of Phytoplankton Death Recycled to Organic Phosphorus	0.5

Phytoplankton Maximum Growth Rate Constant @20 °C (per day)	3
Phytoplankton Growth Temperature Coefficient	1.045
Phytoplankton Carbon to Chlorophyll Ratio	50
Phytoplankton Half-Saturation Constant for Nitrogen Uptake (mg N/L)	0.05
Phytoplankton Half-Saturation Constant for Phosphorus Uptake (mg P/L)	0.005
Phytoplankton Endogenous Respiration Rate Constant @20 °C (per day)	0.1
Phytoplankton Respiration Temperature Coefficient	1.045
Phytoplankton Death Rate Constant (Non-Zooplankton Predation) (per day)	0
Light Option (1 uses input light; 2 uses calculated dial light)	2
Phytoplankton Optimal Light Saturation	500
Background Light Extinction Multiplier	0.5
Detritus & Solids Light Extinction Multiplier	0.1
DOC Light Extinction Multiplier	0.1
Waterbody Type Used for Wind Driven Reaeration Rate	2
Calc Reaeration Option (0=Cover, 1=O'Connor, 2=Owens, 3=Churchill, 4=Tassioglou)	1
Global Reaeration Rate Constant @ 20 °C (per day)	-2
Elevation above Sea Level (meters) used for DO Saturation	41
Reaeration Option (Sums Wind and Hydraulic Ka)	1
Theta -- Reaeration Temperature Correction	1.024
Oxygen to Carbon Stoichiometric Ratio	2.67
BOD (1) Decay Rate Constant @20 °C (per day)	0.045
BOD (1) Decay Rate Temperature Correction Coefficient	1.045
BOD (1) Half Saturation Oxygen Limit (mg O/L)	0.5
Fraction of Detritus Dissolution to BOD (1)	0
BOD (2) Decay Rate @20 °C (per day)	0.024
BOD (2) Decay Rate Temperature Correction Coefficient	1.045
BOD (2) Half Saturation Oxygen Limit (mg O/L)	0.5
Fraction of Detritus Dissolution to BOD (2)	0
BOD (3) Decay Rate Constant @20 °C (per day)	0.111
BOD (3) Decay Rate Temperature Correction Coefficient	1.045
BOD (3) Half Saturation Oxygen Limit (mg O/L)	0.5
Fraction of Detritus Dissolution to BOD (3)	1
Detritus Dissolution Rate (1/day)	0.4
Temperature Correction for detritus dissolution	1.045

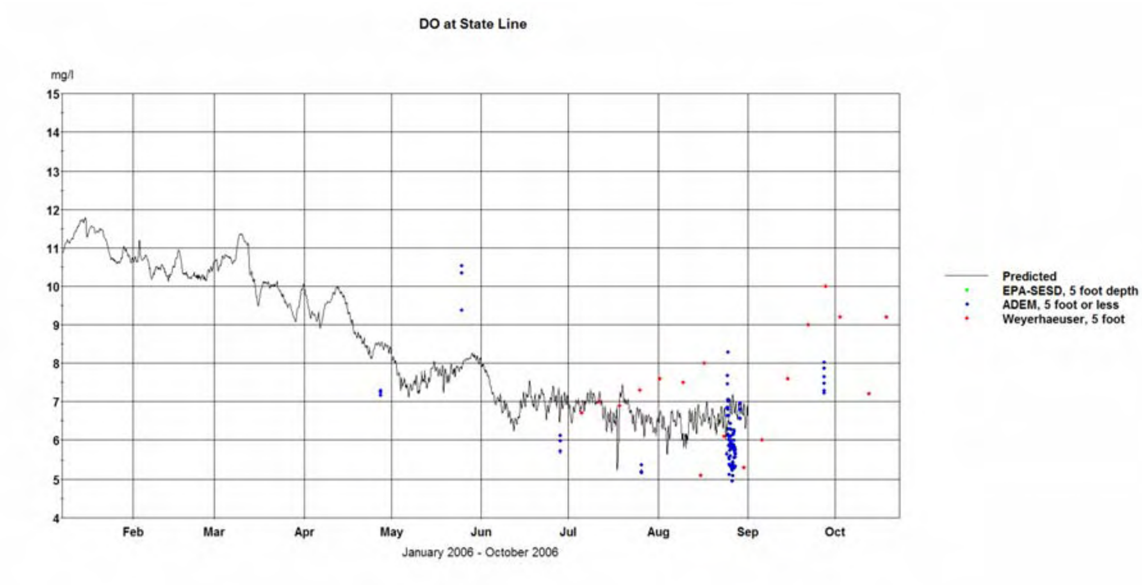


Figure 30: Predicted and Observed DO at state line, zoomed to 2006.

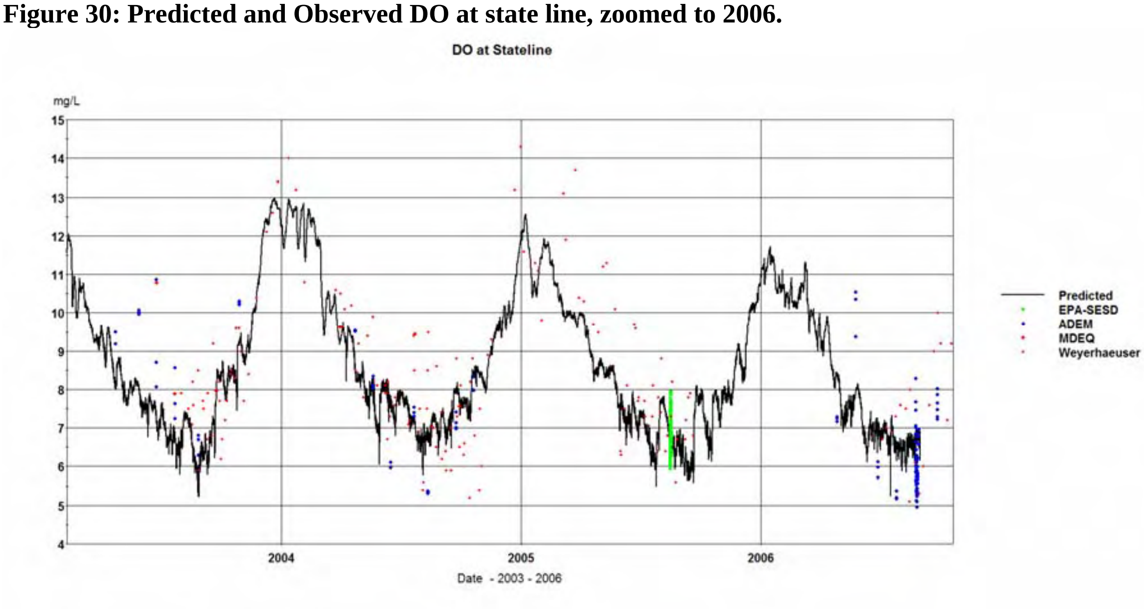


Figure 31: Predicted and Observed DO at state line for 2003 through 2006.

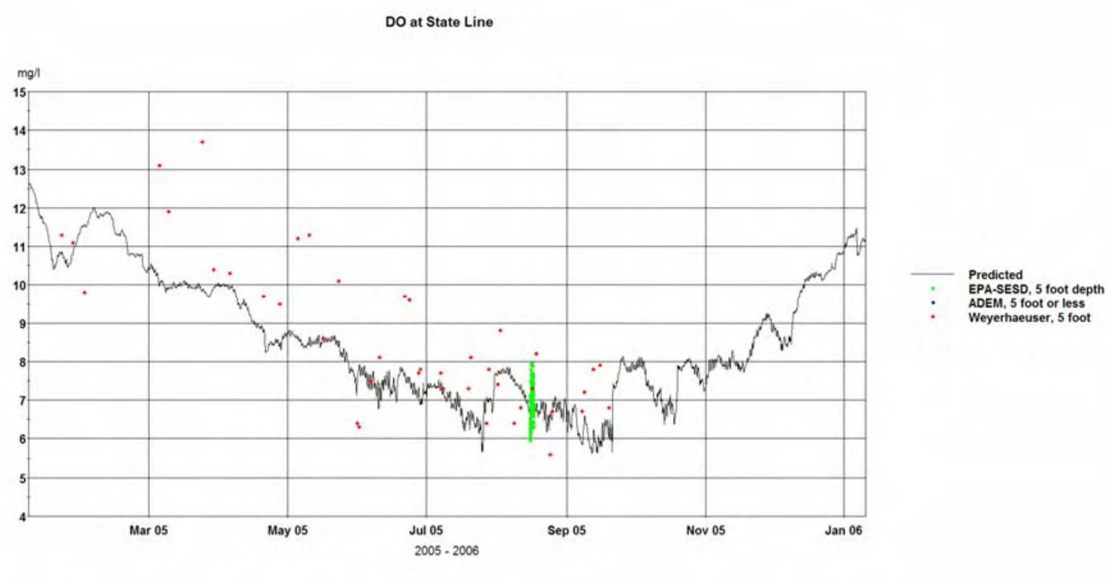


Figure 32: Predicted and Observed DO at state line for 2005.

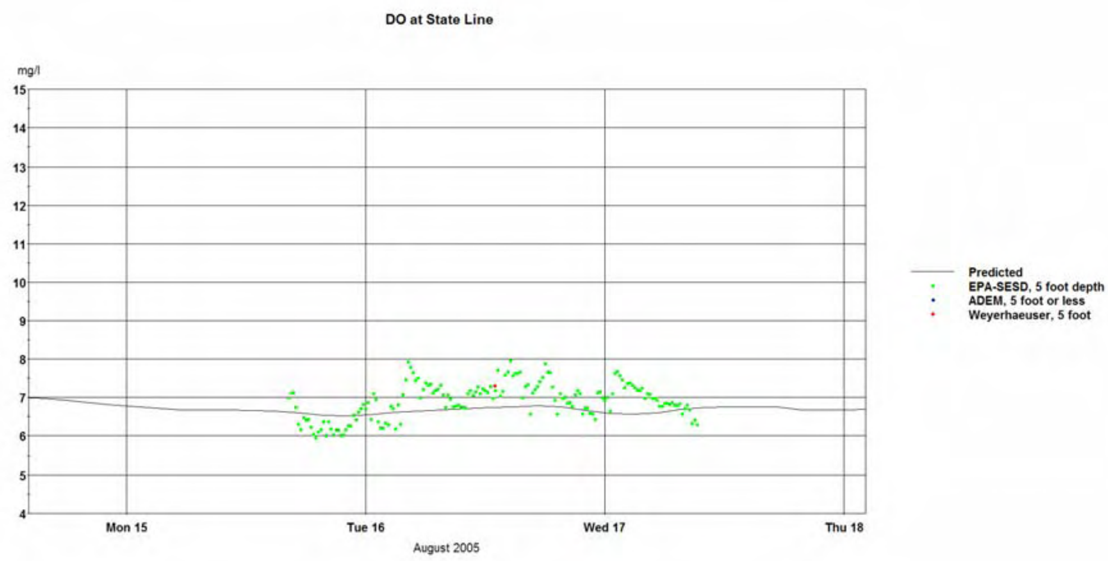


Figure 33: Predicted and Observed DO at state line, zoomed to August 2005 EPA Water Quality Study period.

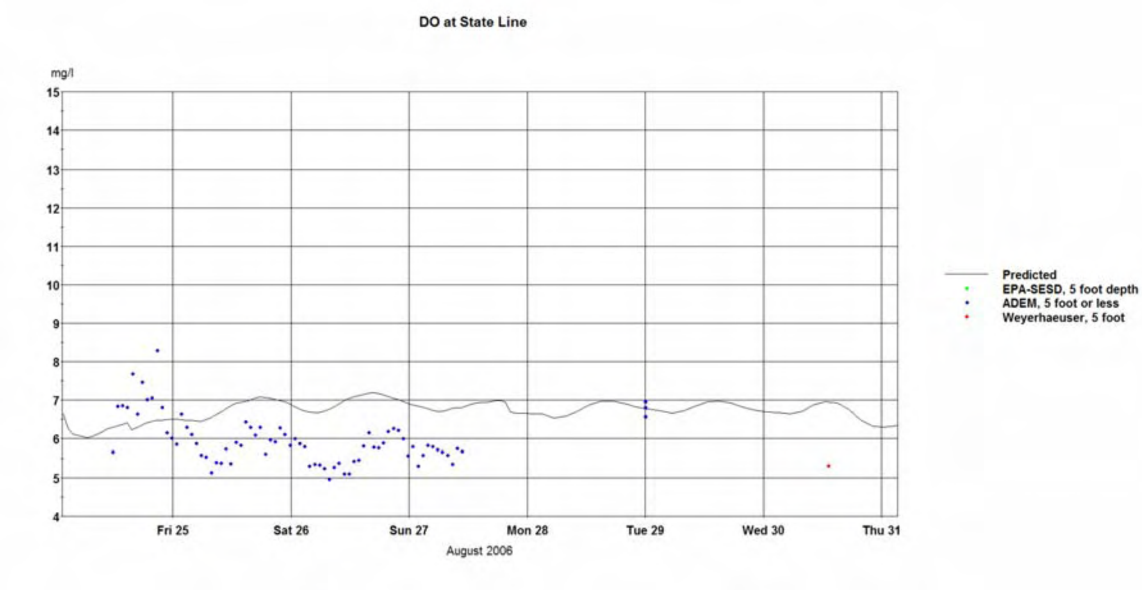


Figure 34: Predicted and Observed DO at state line, zoomed to August 2006 ADEM diurnal data collection.

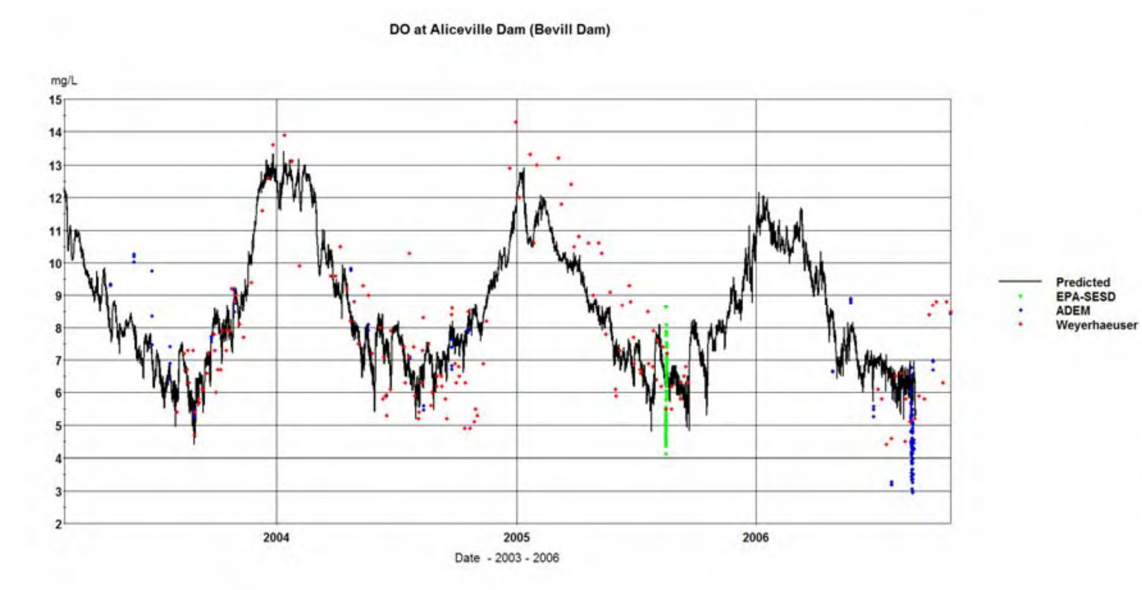


Figure 35: Predicted and Observed DO at Aliceville Dam for 2003 through 2006 period.

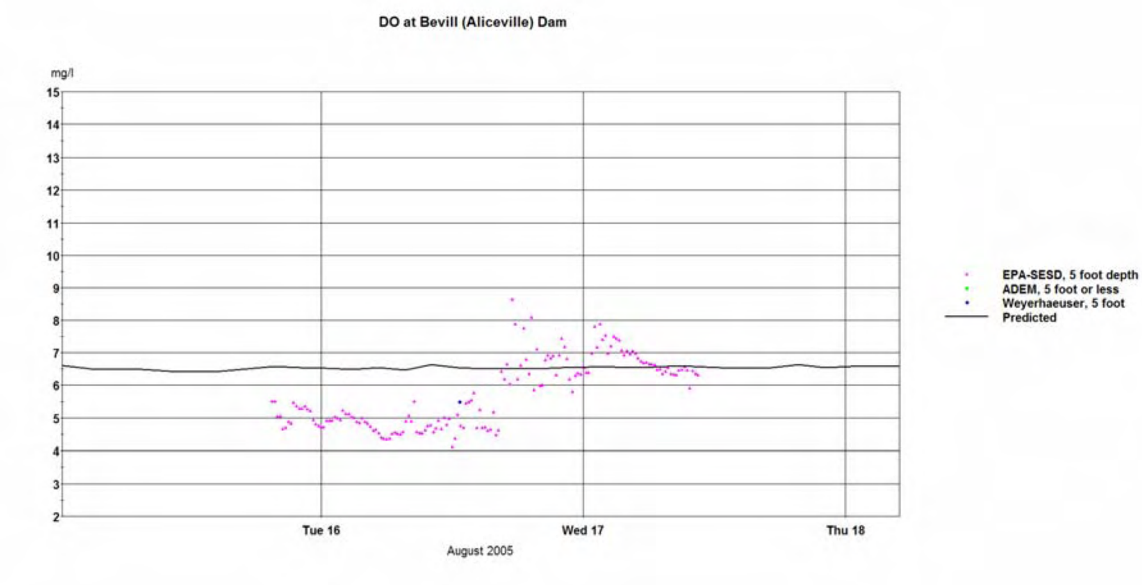


Figure 36: Predicted and Observed DO at Aliceville Dam, zoomed to August 2005 Water Quality Study.

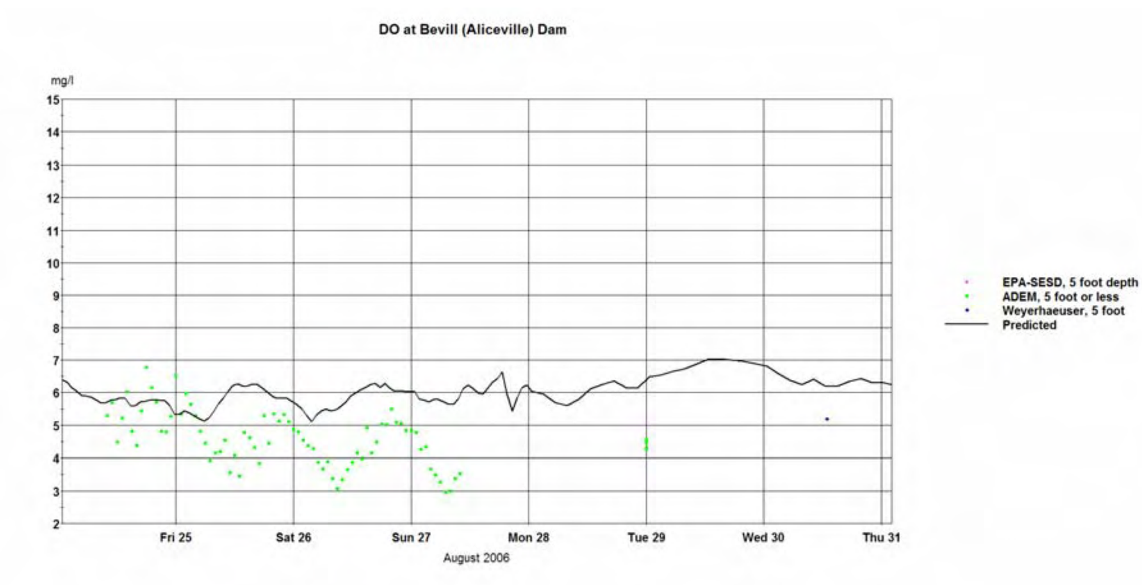


Figure 37: Predicted and Observed DO at Aliceville Dam, zoomed to August 2006 ADEM diurnal data collection.

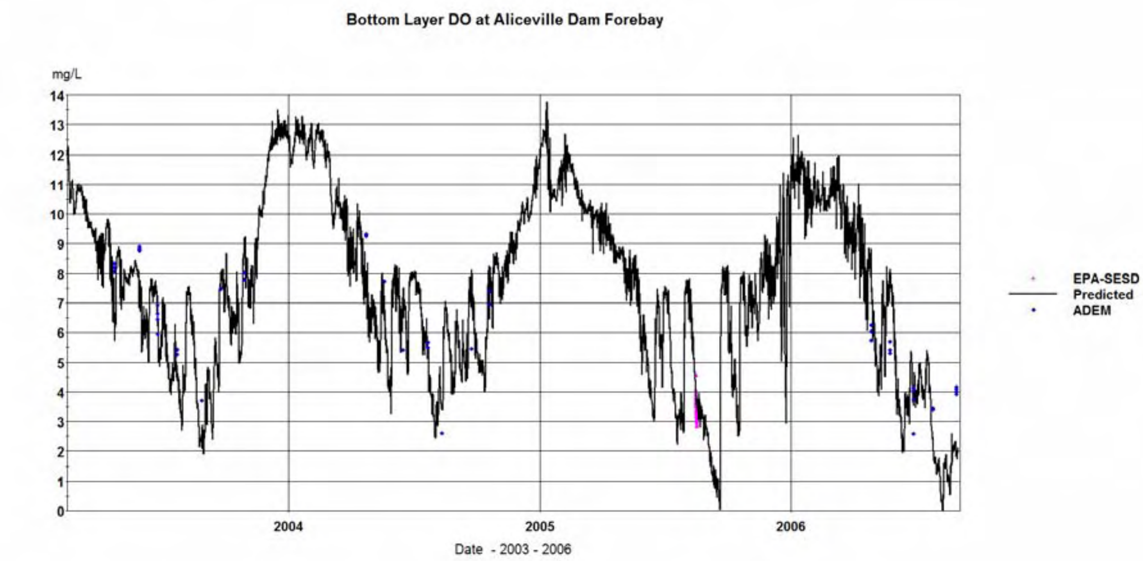


Figure 38: Bottom DO Aliceville Dam. The measured SOD rate was decreased until the predicted bottom layer DO matched the measured DO in the bottom layer.

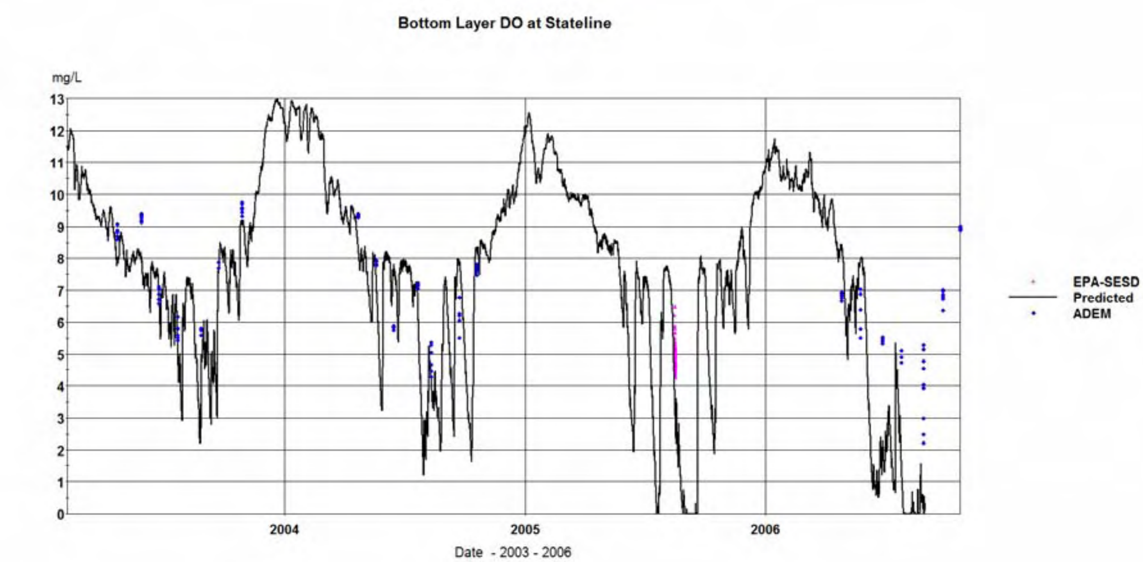


Figure 39: Bottom DO Stateline. The measured SOD rate was decreased until the predicted bottom layer DO matched the measured DO in the bottom layer.

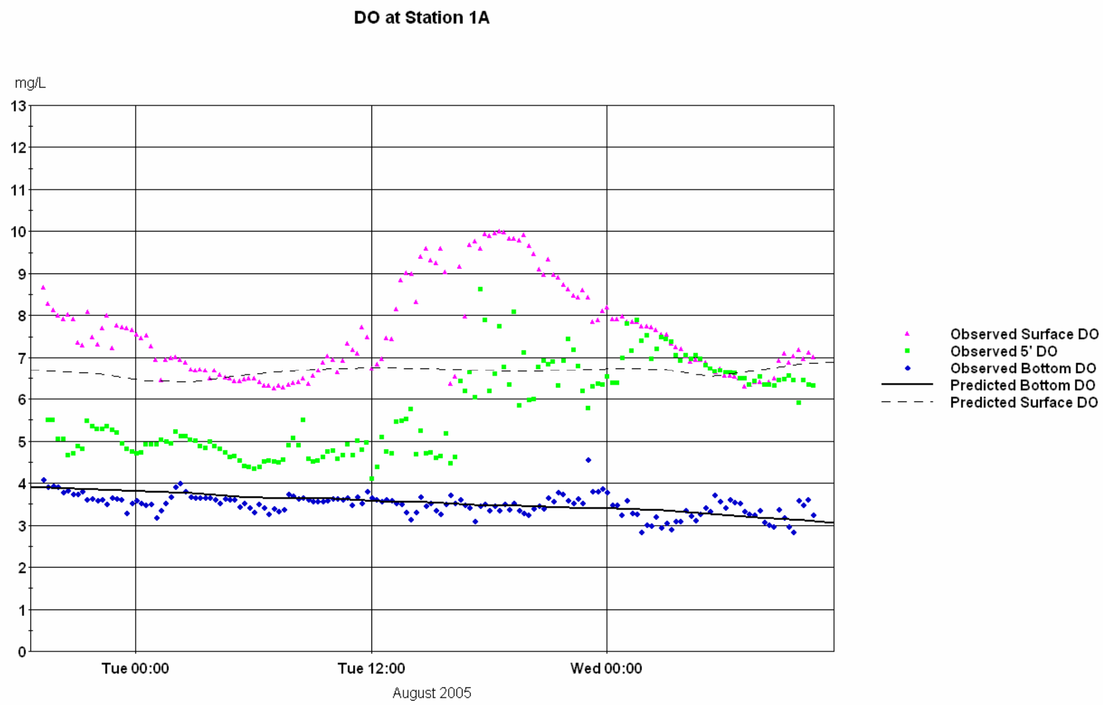


Figure 40: DO Profile Predicted and Observed at Station 1A.

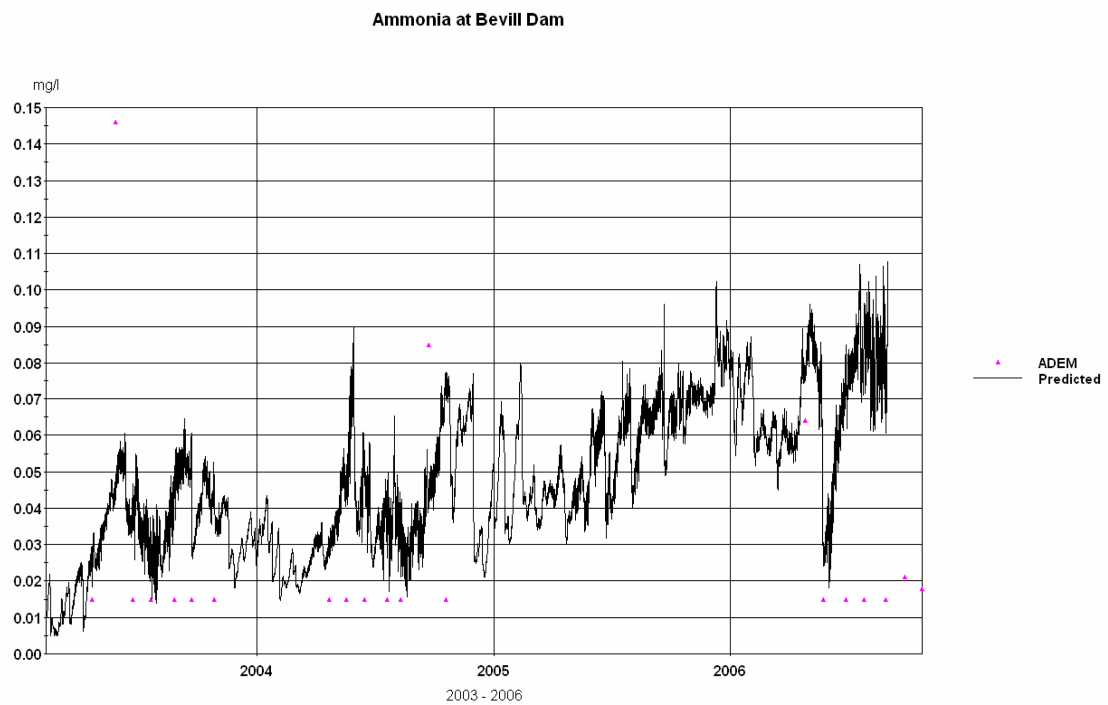


Figure 41: Predicted and Observed Ammonia at Aliceville Dam.

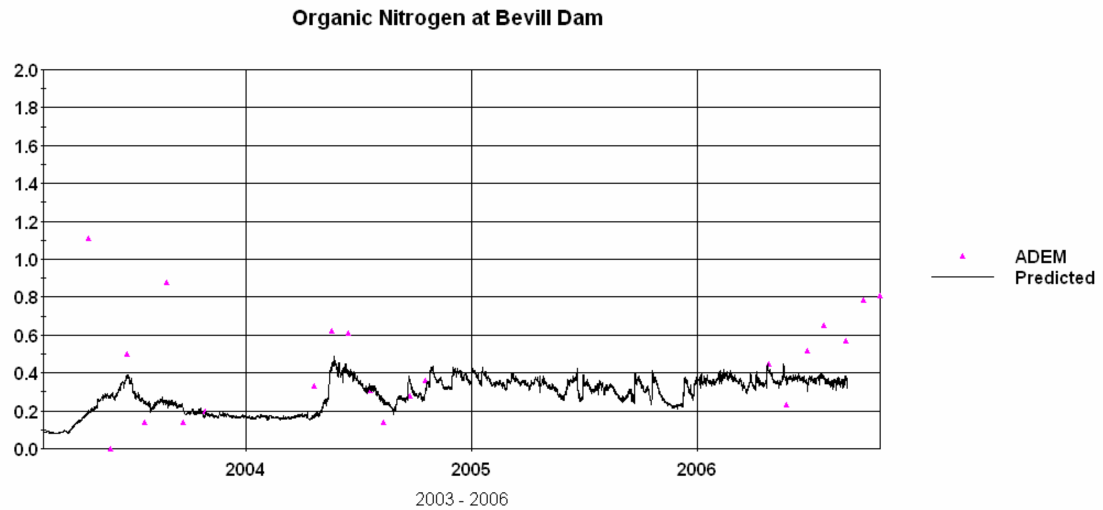


Figure 42: Predicted and Observed Organic Nitrogen at Aliceville Dam.

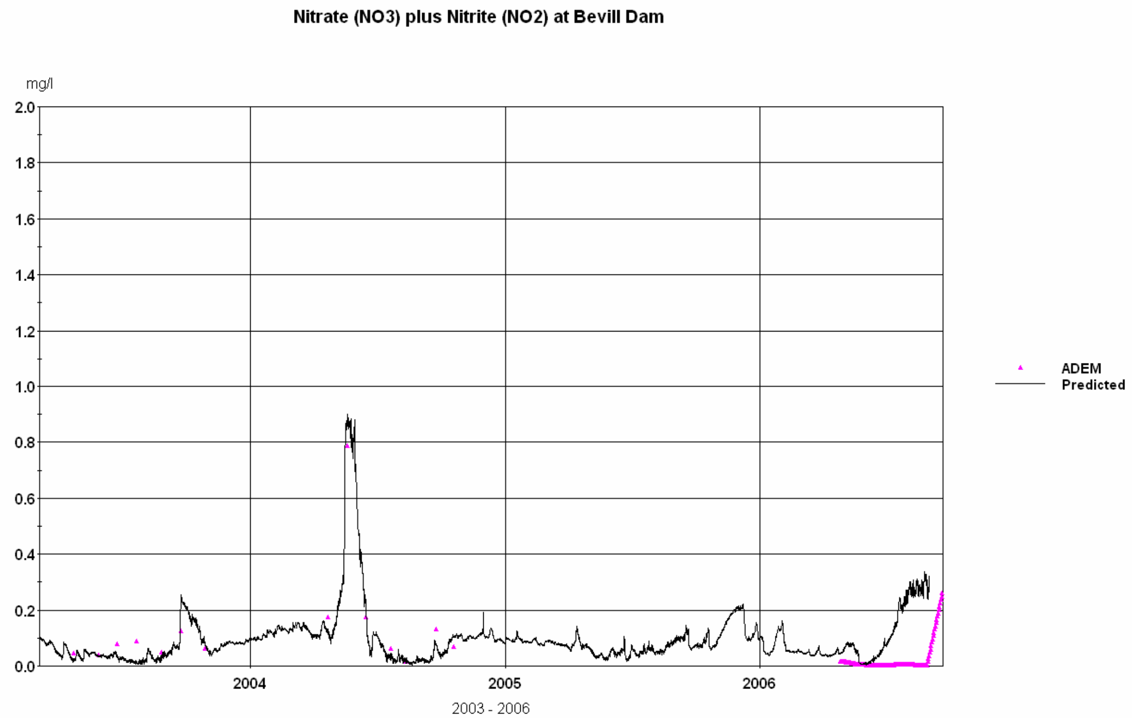


Figure 43: Predicted and Observed Nitrate plus Nitrite at Aliceville Dam.

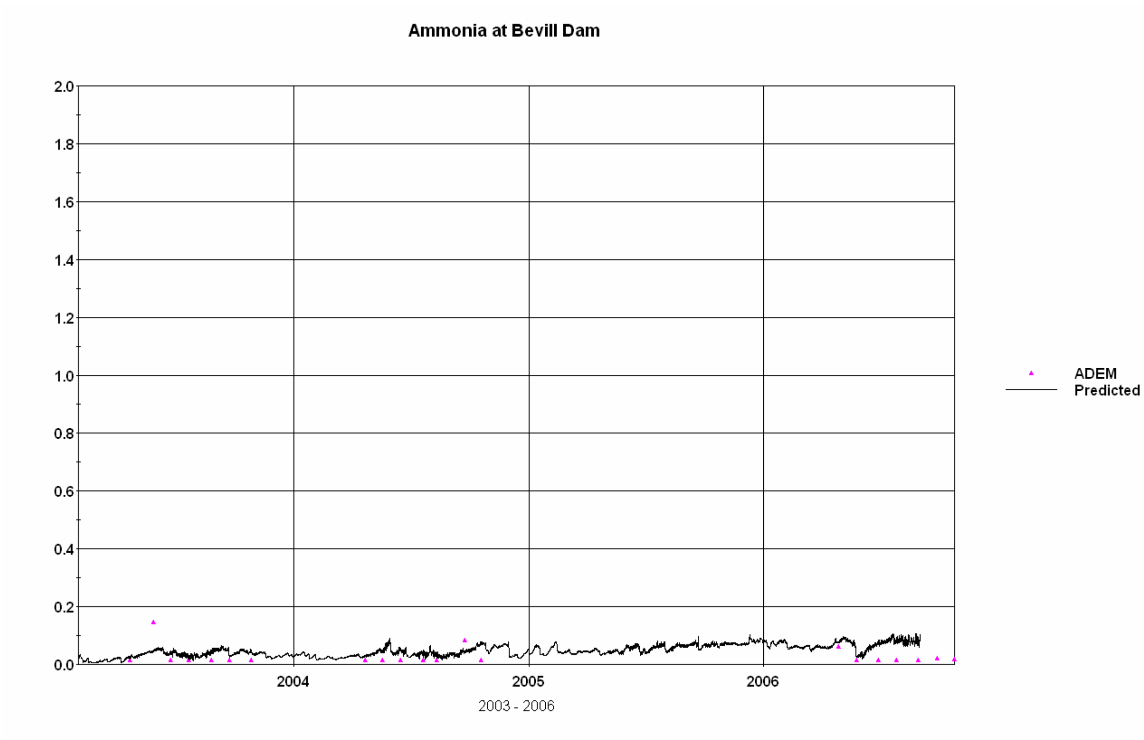


Figure 44: Predicted and Observed Ammonia at Aliceville Dam.

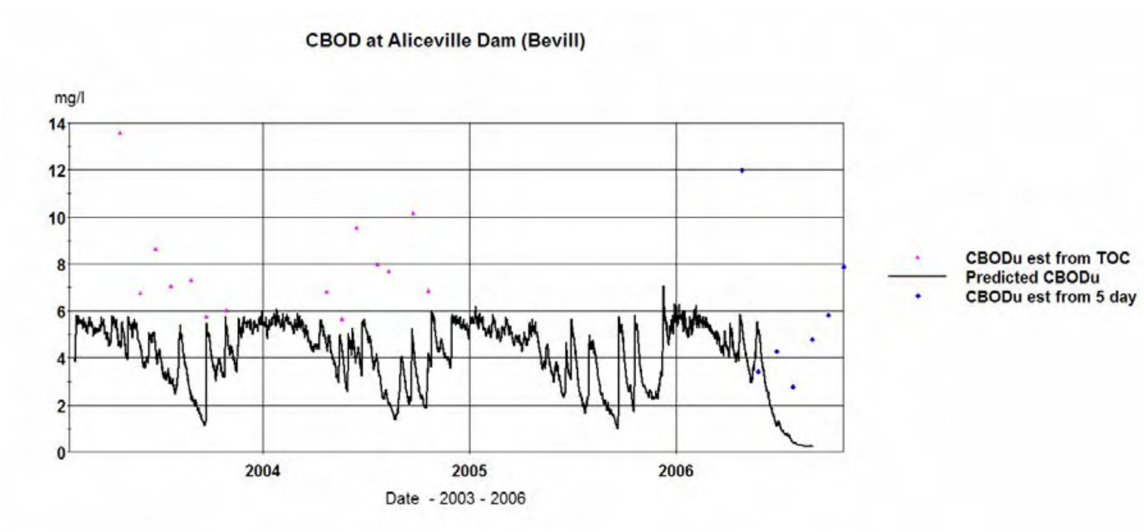


Figure 45: Predicted and Observed CBODu at Aliceville Dam.

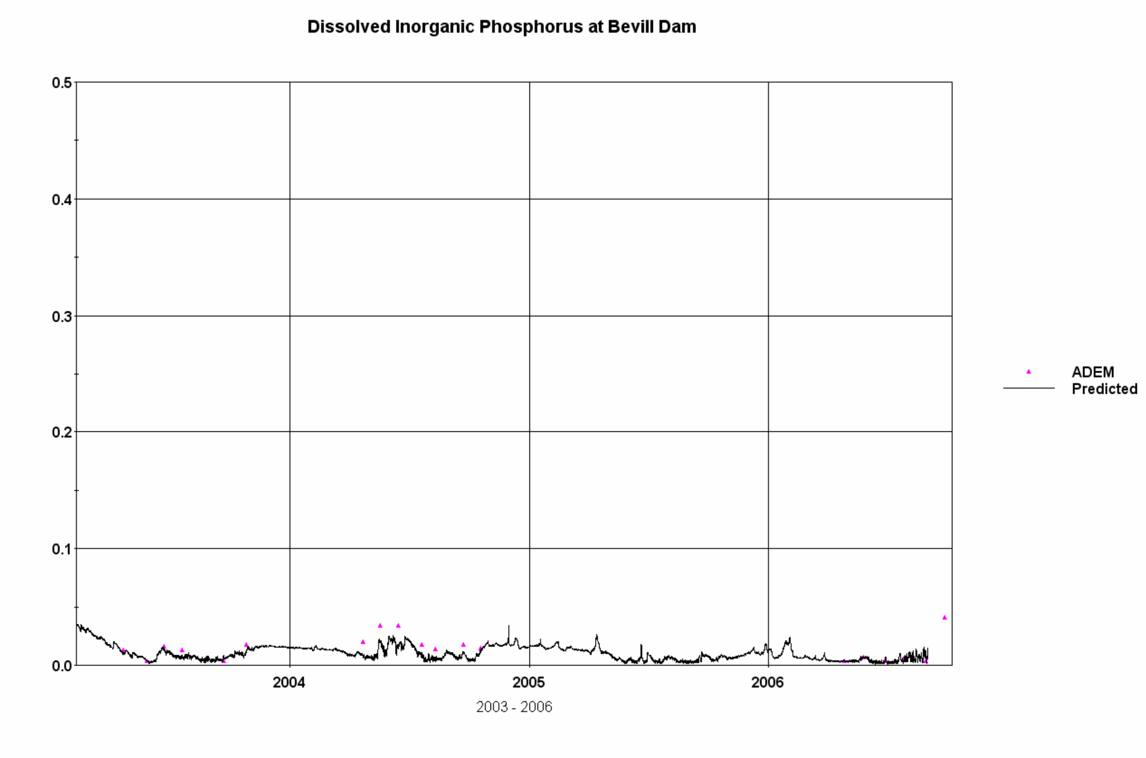


Figure 46: Predicted and Observed Dissolved Inorganic Phosphorus at Aliceville Dam.

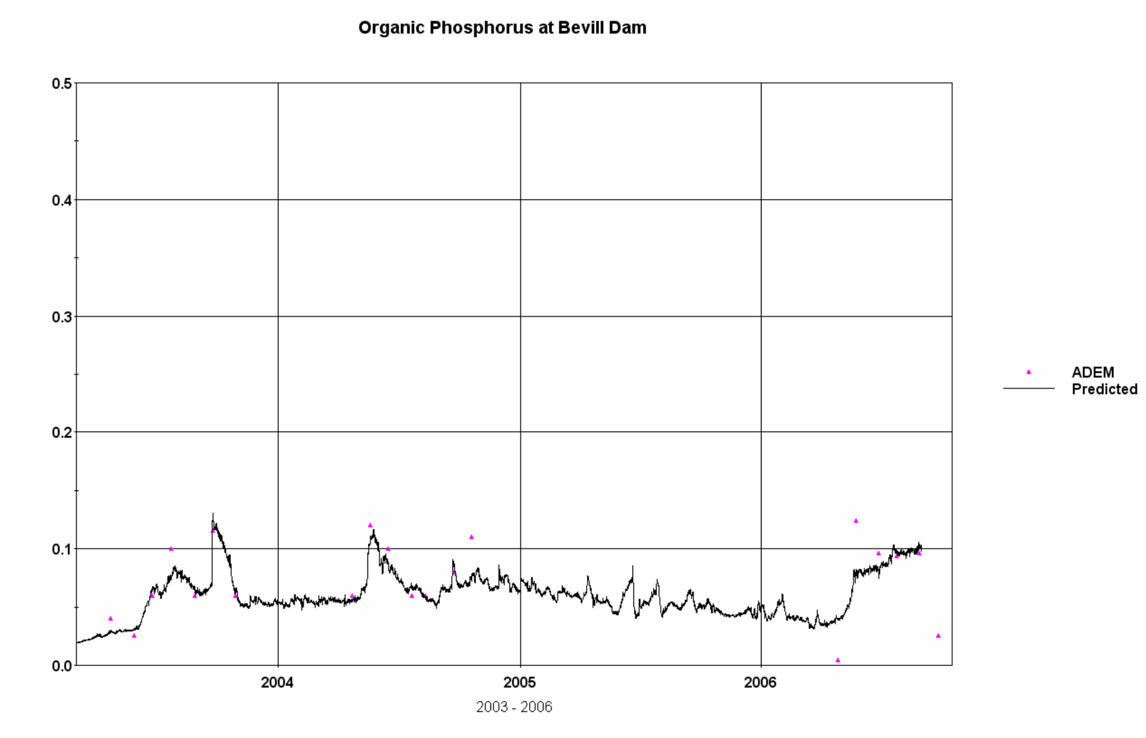


Figure 47: Predicted and Observed Organic Phosphorus at Aliceville Dam.

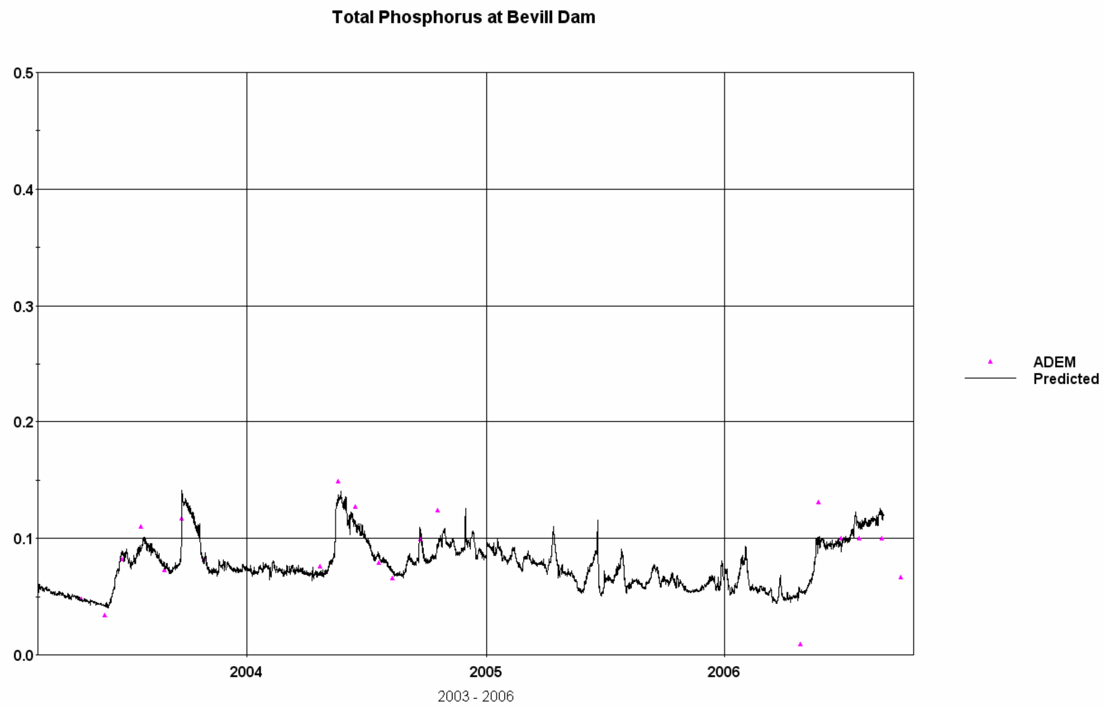


Figure 48: Predicted and Observed Total Phosphorus at Aliceville Dam.

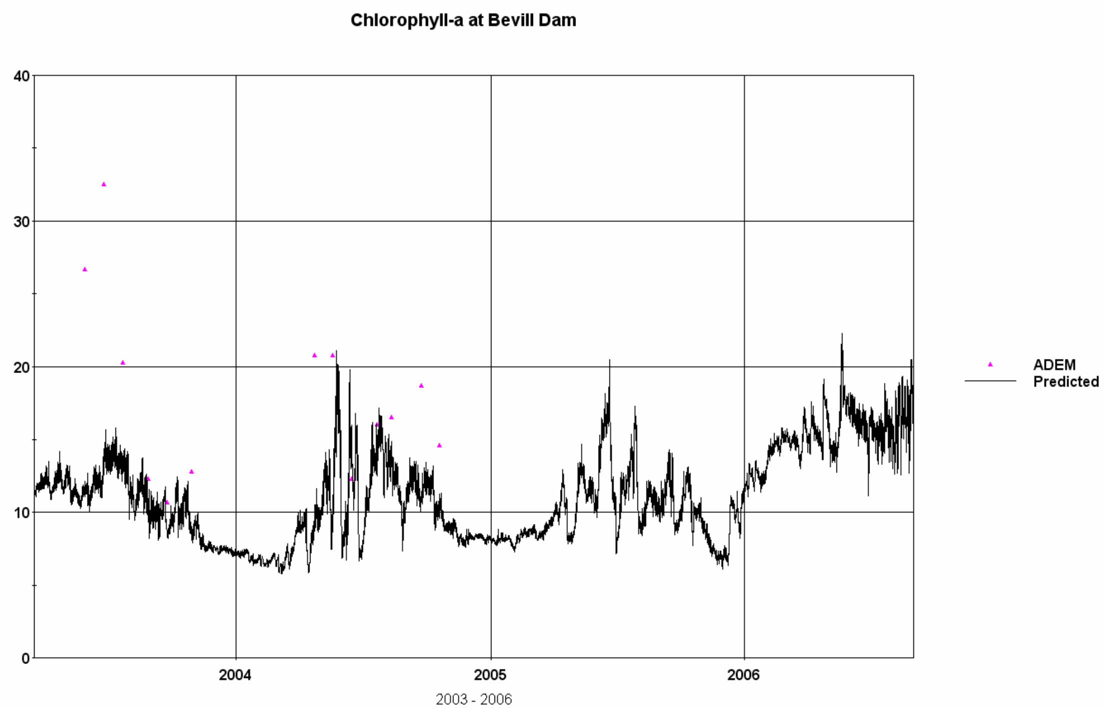


Figure 49: Predicted and Observed Chlorophyll-a at Aliceville Reservoir Station 1A.

9 Model Reduction Scenarios

After the model was calibrated, this model was used as a predictive tool. Scenarios of reduced loadings were analyzed to determine the maximum load that could be assimilated while attaining the DO water quality criteria. The lowest DO has been observed in the Aliceville pool at station 1A near the Bevill Lock and Dam. The model also shows this as the critical location. Pollutant loadings were reduced in the model until model predictions at station 1A showed the DO was attained. As discussed previously, the model divides the water column into one to five layers depending on the depth of each segment. Each layer of the model is generally 1.3 meters (4.26 feet), so the top layer represents the top 1.3 meters of the water column and the top two layers represent the top 2.6 meters (8.5 feet). A volume weighted average of the top two layers was compared to the water quality standard of 5.0 mg/L. Several alternatives are discussed next.

The first model alternative indicates that a 30 percent reduction from existing conditions in point source and non-point source total nitrogen, total phosphorus, and BOD loads improves the DO to the water quality standard of 5 mg/L at a depth of 5 feet. This alternative implies that existing loading to the reservoir and surrounding watershed should be reduced by 30 percent. The allowable loads under this alternative are shown in Figure 50. These loads are the maximum daily load that will attain and maintain the water quality criteria during the critical conditions experienced each summer. Under this alternative the loadings for the non-summer months can be higher, as long as the annual average loads do not exceed those in Figure 51.

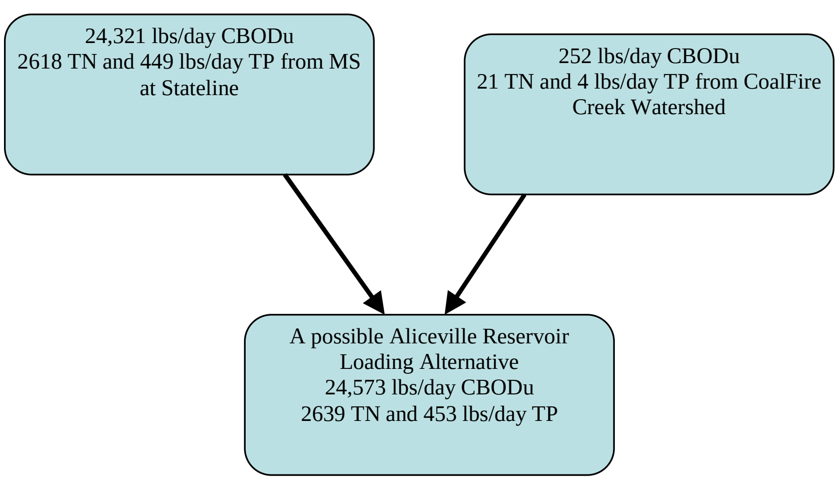


Figure 50: Alternative June through September Loads to meet Water Quality Standards.

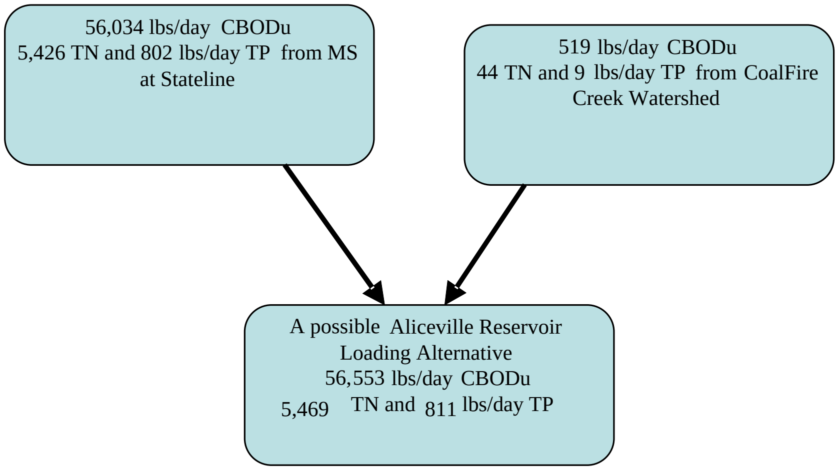


Figure 51: Alternative Annual Average Loads to meet Water Quality Standards.

A second alternative that achieved the DO water quality standard was 50 percent removal of BOD from the system. This would require a 50 percent reduction in BOD loadings from existing point sources and non-point sources. Under this scenario neither nitrogen nor phosphorus loads were reduced.

A scenario that did not attain water quality standards, but worth mentioning was removal of the four local point source discharges (Weyerhaeuser, The City of Columbus WWTP, EKA Chemical and Sanderson) to the Aliceville pool. This scenario did not achieve the DO standard, and this reveals that a reduction from non-point sources is necessary. This is not surprising since non-point sources contribute the majority of BOD and nitrogen loads, and about half of the phosphorus load to Aliceville Reservoir.

Another alternative that was examined was reduction from NPDES permit limits. Under this scenario, loads from NPDES permitted discharge facilities were entered at permit limits. For the facilities upstream of the model boundary, the effect of permit limit loads at the boundary was estimated. A reduction of TN, TP, and BOD point and non-point source loads of about 55 percent was necessary to achieve the DO standard. Table 11 below shows the percent of permitted discharge that each facility is currently discharging.

Table 11: Same as Table 4: Existing discharge as percent of Permit Limit for Major NPDES Facilities of BOD and Ammonia to the Tombigbee River Upstream of Aliceville Reservoir.

HUC	NPDES Permit #	Facility Name	Facility Type	5- day BOD Limit (lb/d)	Ammonia (lb/d)
03160101	MS0001783	Bryan Foods	Meat Packing	14%	16%
03160101	MS0003158	True Temper Sports/Emhart	Plating	NA	NA
03160101	MS0045489	Amory POTW	Sewerage	14%	39%
03160101	MS0055581	Aberdeen POTW	Sewerage	19%	NA
03160103	AL0048372	Hamilton POTW	Sewerage	7%	1%
03160104	MS0020788	West Point POTW	Sewerage	13%	50%
03160102	MS0036111	Tupelo POTW	Sewerage	22%	5%
03160105	AL0023400	Winfield POTW	Sewerage	12%	69%
03160105	MS0023868	Columbus POTW	Sewerage	11%	7%
03160106	MS0036412	Weyerhaeuser CPPC	Paper Mill	12%	NA
03160106	MS0040215	EKA Chemical	Chemical	NA	NA
03160105	MS0002216	Sanderson	Wood Products	NA	NA

The table shows that all facilities are discharging below their permit limit of BOD and ammonia. Since the facilities are well below permit limits, the reductions of BOD and ammonia could be implemented through reductions from non-point sources, along with TN and TP reductions from both point and non-point sources. The facilities do not have permit limits for TN (with one exception) or TP, and this alternative shows a fifty-five percent reduction from point sources of existing TP, organic nitrogen, and nitrate and nitrite nitrogen is necessary.

To understand the effects of nutrient reductions on Aliceville Reservoir another set of alternatives were analyzed. These include an alternative with a 30 percent reduction of nitrogen, an alternative with a 30 percent reduction in phosphorus, and an alternative with 30 percent reduction of both nitrogen and phosphorus. Figure 52 shows that nutrient reductions improve the DO in Aliceville Reservoir at station 1A. Figure 53 shows that DO excursions below 5 mg/L is less frequent after nutrient reductions. The Aug. and Sept. frequency of excursions below the water quality standard of 5.0 is decreased from 2% to about 1%. Also, Table 12 shows that chlorophyll-a concentrations decrease as much as 5 ug/L after nutrients are reduced 30 percent.

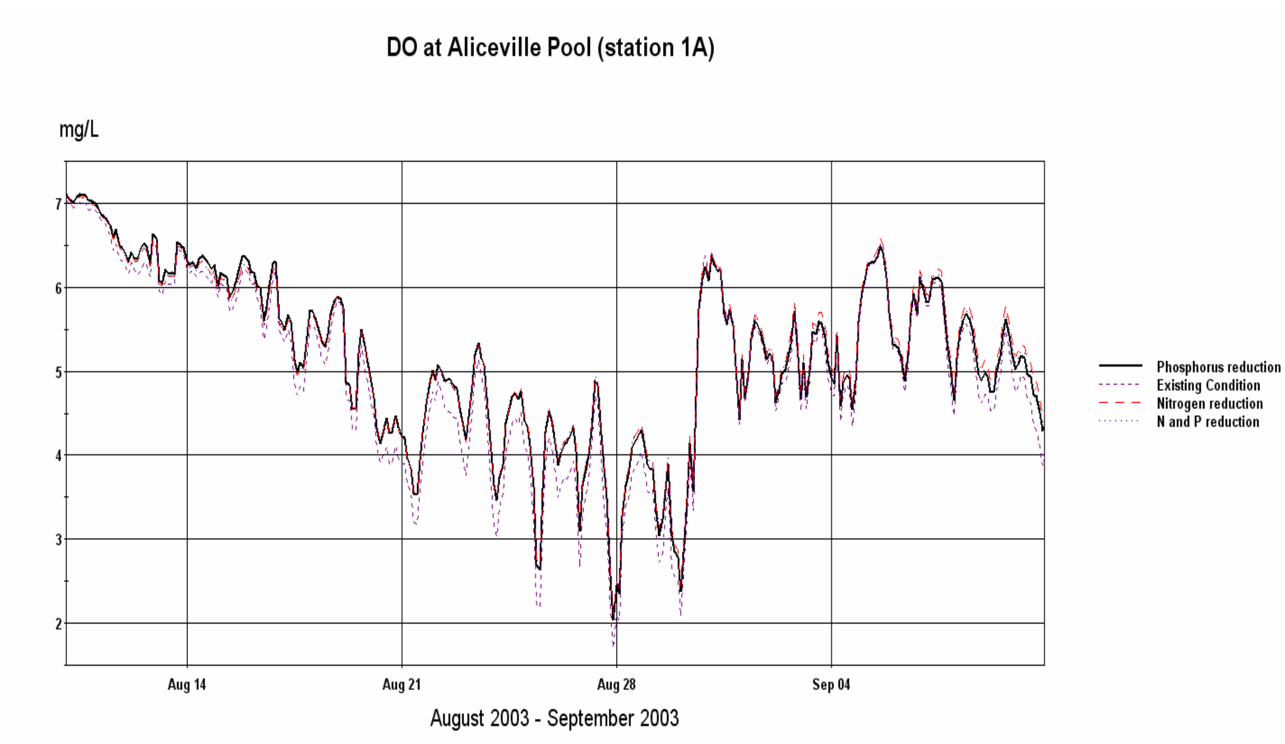


Figure 52: Predicted DO response under nutrient reduction model alternatives. Dashed line with lowest dips is the existing conditions alternative. All other lines are with nutrient reductions.

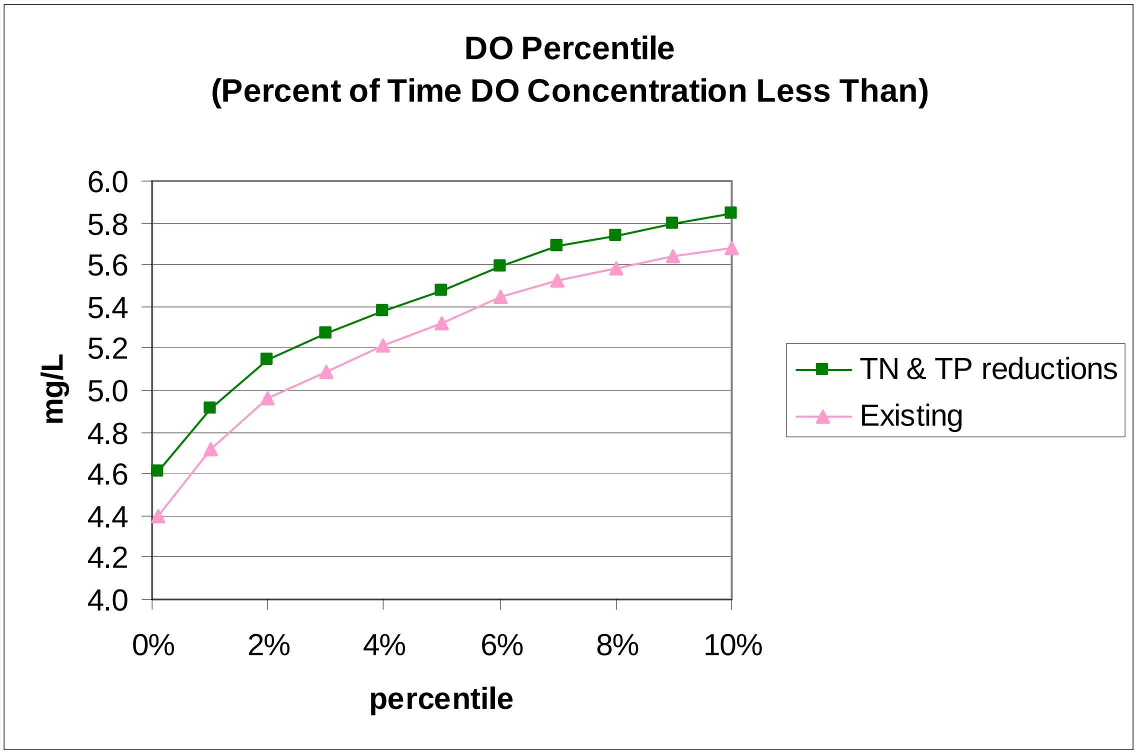


Figure 53: Nutrient reductions improve the DO. The Aug. and Sept. frequency of excursions below the water quality standard of 5.0 is decreased from 2% to about 1%.

Table 12: Growing Season Chlorophyll-a Concentrations Under Nutrient Reductions.

Growing Season (May - August) Chla (ug/l)				
Year	Exisitng	30% TN Reduction	30% TP Reduction	30% TN &TP Reduction
2003	13.7	12.7	14.1	12.6
2004	14.8	14.8	14.7	13.4
2005	15.1	13.6	13.3	13.0
2006	22.9	21.8	18.1	18.0

The above analyses lead to a final alternative that demonstrates one possible way to meet the DO criteria for Aliceville Reservoir. After examining the sources of pollutant loads to Aliceville Reservoir and the load reduction necessary to achieve water quality standards, another load allocation alternative was developed. Under this alternative water quality standards are achieved by reducing the major contributors of pollutant loads. Figure 3 shows that the current BOD load is primarily from non-point sources (92%), and Weyerhaeuser (7%), and other point sources contribute less than 1%. So this alternative includes BOD reductions from non-point sources and the largest point source. Figure 3 also shows that 98 percent of the total nitrogen load is from non-point sources. Thus, TN reductions are included from non-point sources. The sources of the total phosphorus load are shown in Figure 5. This figure shows that phosphorus loading to Aliceville Reservoir comes from point and non-point sources in similar proportions, with 44% from all point sources and 56% from non-point sources. Therefore, TP reductions are included from all point source facilities and non-point sources.

In summary, this alternative includes a 30 percent reduction from non-point sources of BOD, TN, and TP. Also, total phosphorus is reduced 30 percent from all point sources. In addition, since the largest BOD point source currently contributes a major portion of the BOD loading and this would be a larger percent after reductions, a BOD reduction of 30% is included from this source. The allocations for this alternative are shown in Table 13 in terms of percent reductions from existing conditions.

Table 13: Allocation for one possible way to meet the water quality criteria

Percent reduction from Existing loads	BOD	TN	TP
Largest BOD Point Source	Existing -30%	Existing	Existing -30%
Other Point Sources	Existing	Existing	Existing -30%
Non-point Sources	Existing -30%	Existing -30%	Existing -30%

For comparison purposes, the reductions necessary to achieve the EPA recommended nutrient criteria are described next. As part of EPA’s National Strategy For The Development Of Regional Nutrient Criteria, published in June 1998, EPA developed ambient water quality criteria recommendations for lakes and reservoirs in nutrient ecoregion IX. This nutrient ecoregion is an aggregate of level III ecoregions that includes most of Alabama and Mississippi. This recommended criteria for chlorophyll-a ranges from 4.9 to 6.5 ug/L depending on the analytical method performed in the laboratory (e.g. fluorometric, spectrophotometric, or trichromatic). The recommended criteria for TN is 0.397 mg/L, and for TP the value is 0.020 mg/L. The average chlorophyll-a observed under existing conditions at Aliceville Dam was 15.8 ug/L and the maximum was 32 ug/L. The average TN at Aliceville Dam was 0.57 mg/L and the maximum was 1.4. The average TP at Aliceville Dam was 0.087 mg/L and the maximum was 0.15 mg/L. The percent reductions in order to achieve the recommended criteria are shown in Table 14. These are recommended nutrient criteria for waters that do not have enough available site specific information from which to develop criteria. Here, these recommended values are shown for comparison purposes only, and the site specific analyses and modeling are used for the low DO TMDL. Aliceville Reservoir is not on the 303(d) list as impaired for nutrients, however, nutrient enrichment is evident and, reductions in nutrient loadings are required to achieve the DO TMDL.

Table 14: Reduction to achieve recommended nutrient criteria.

	CHLA ug/L	TN mg/L	TP mg/L
EPA nutrient ecoregion IX recommended criteria	5.54	0.397	0.02

Average Observed	15.8	0.57	0.087
Maximum Observed	32	1.4	0.15
Percent Reduction of average	65%	30%	77%

10 References

GAEPD. 2004. Long-term BOD Analysis Program. LtBOD Version 3.0. Georgia Environmental Protection Division.

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USEPA. 2001. Water Quality Analysis Simulation Program (WASP) Version 6.0, Draft User's Manual. Wool, T.A., Ambrose, R.B., Martin J.L., Comer, E.A.

USEPA. 2006. Tennessee-Tombigbee Waterway Water Quality Study, Columbus, Mississippi. Project Nos. 05-0521 and 05-0522, Science and Ecosystem Support Division, U.S. Environmental Protection Agency, Athens, GA.

USEPA. 2000. Ambient Water Quality Criteria Recommendations For Lakes And Reservoirs In Nutrient Ecoregion IX. EPA-822-B-00-011. December 2000.

Appendix A Long-term BOD Analysis

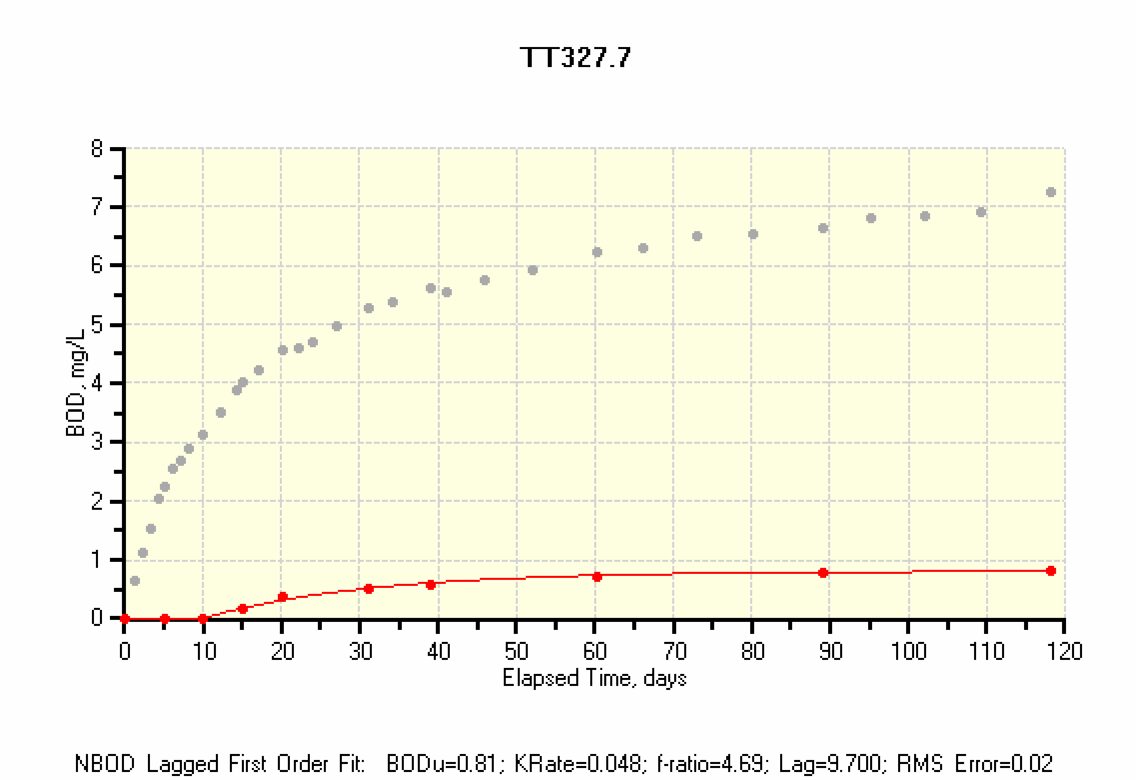


Figure 54: NBOD for TT327.7

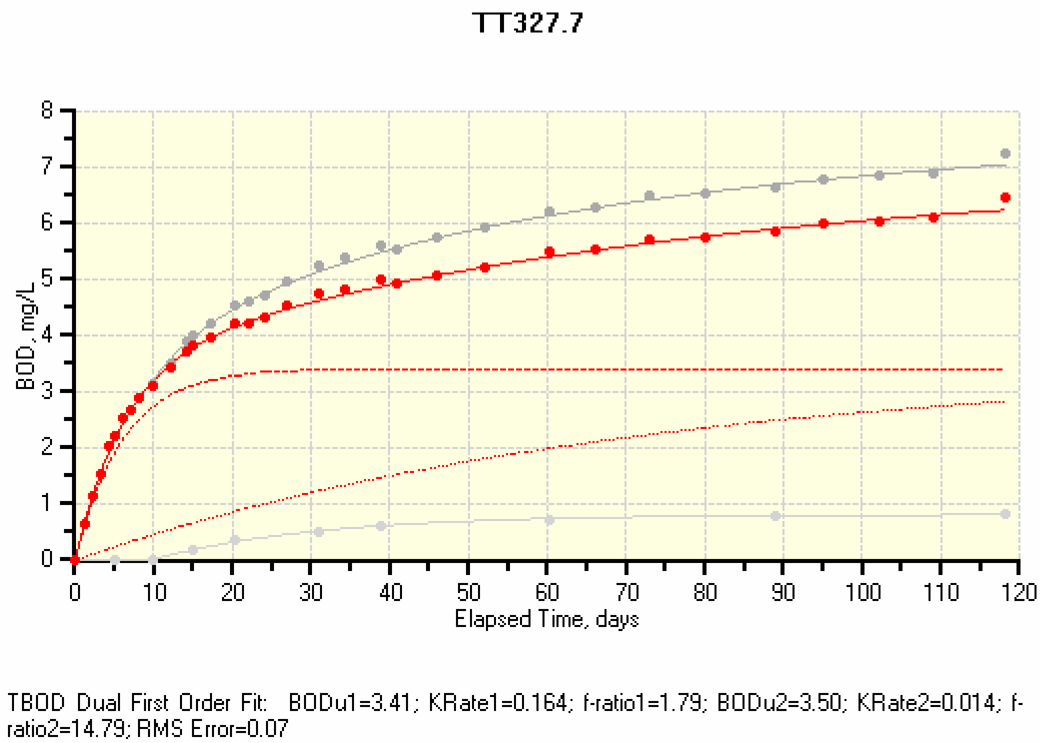


Figure 55: Dual first order BOD rate for TT327.7

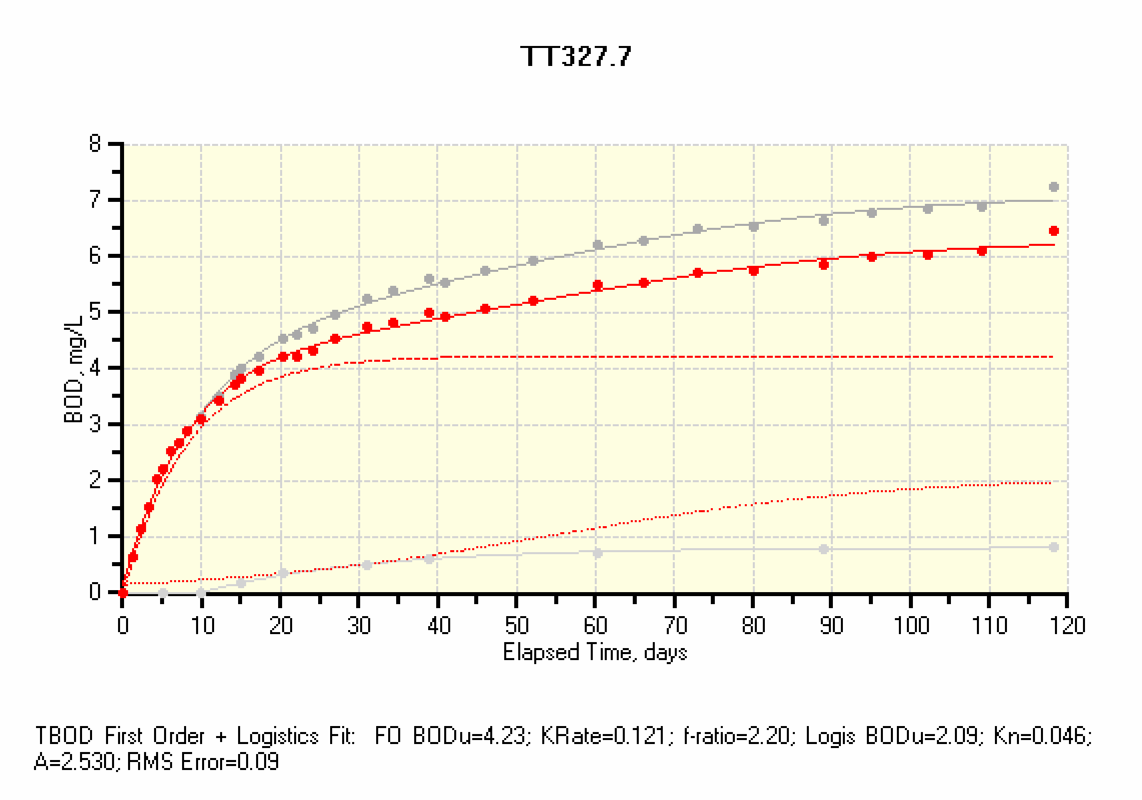


Figure 56: Station TT327.7, dual BOD rate is the same data as previous figure, but shifted to first order plus logistics. The RMS error is about the same.

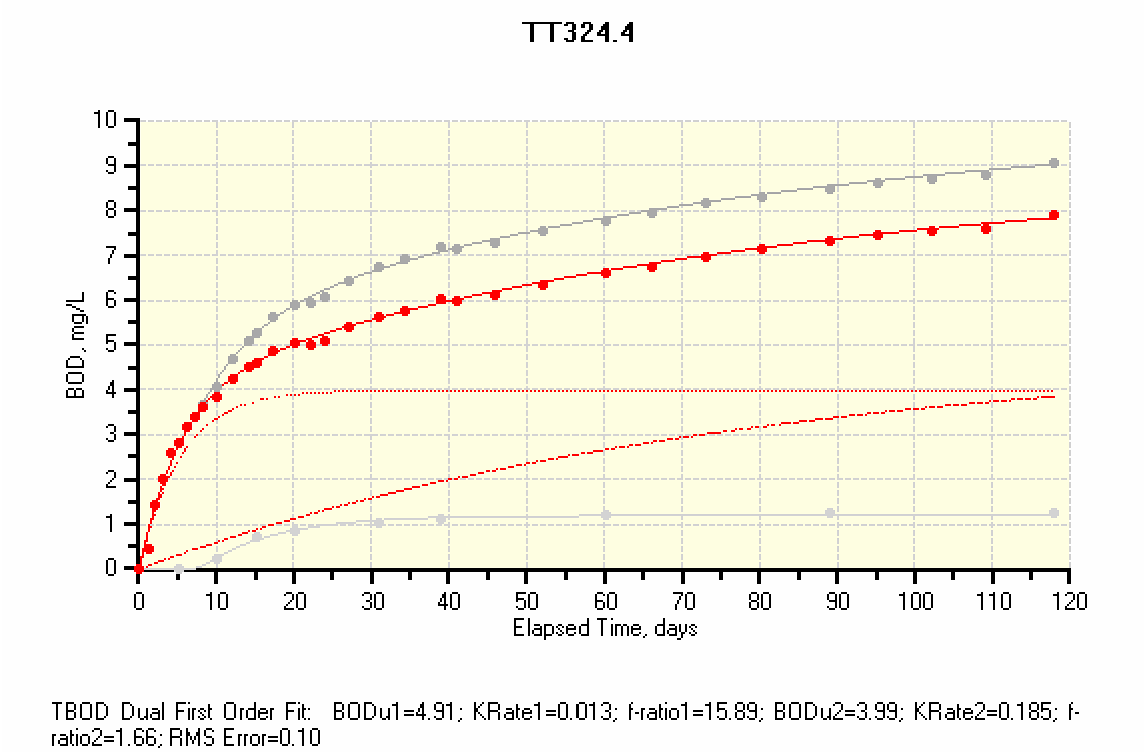


Figure 57: BOD rates for TT324.4

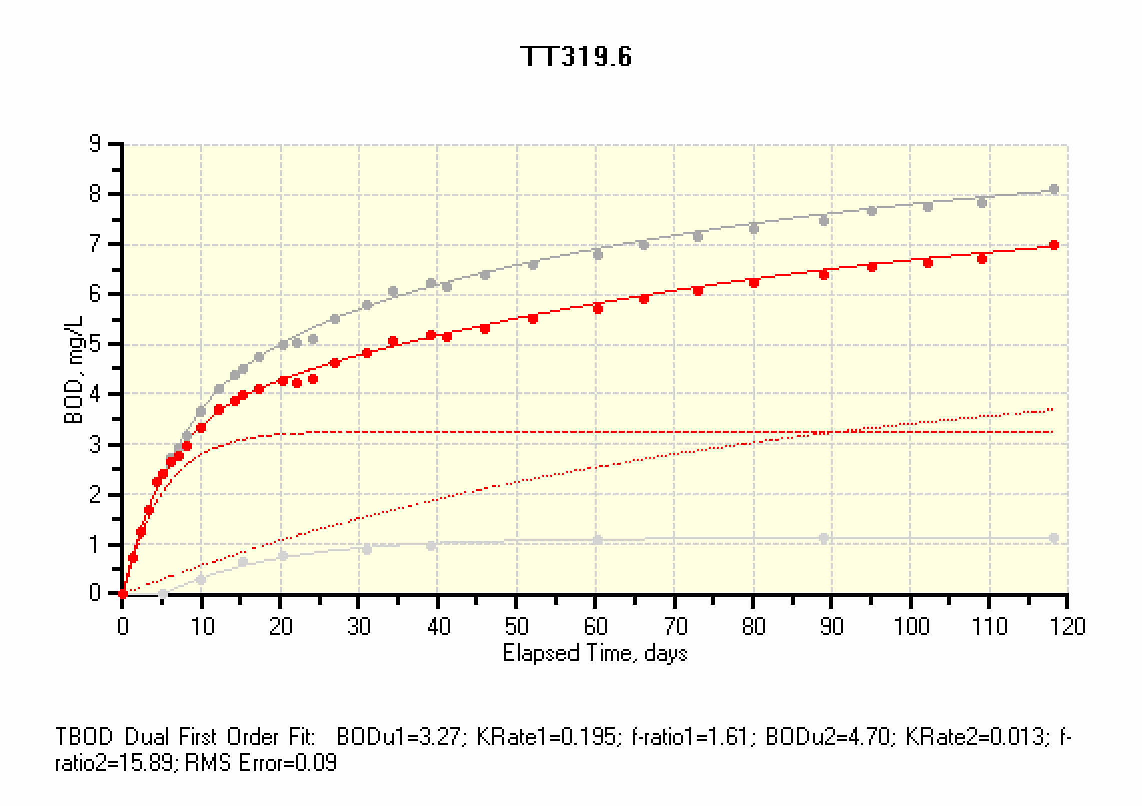


Figure 58: BOD rates for reservoir station TT319.6

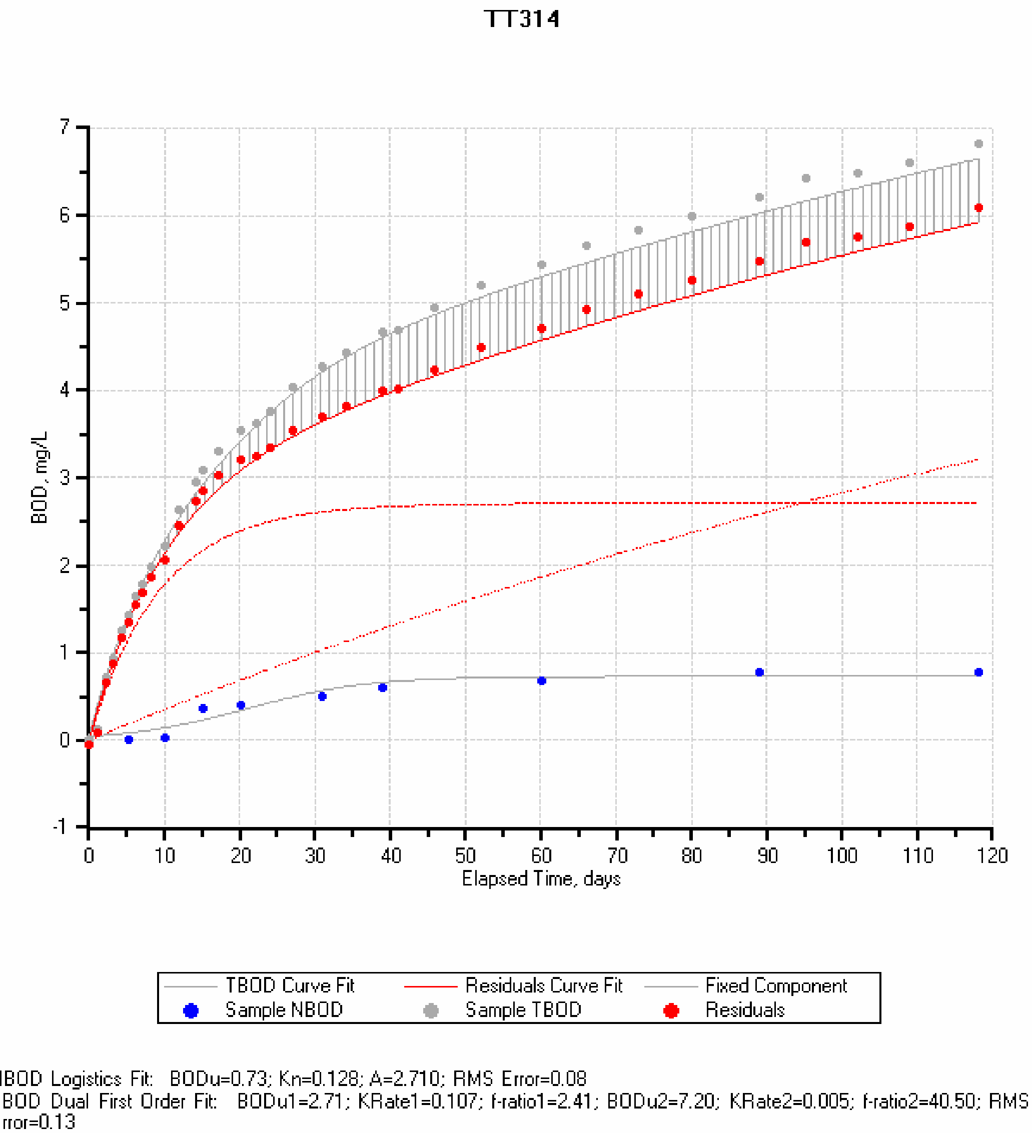
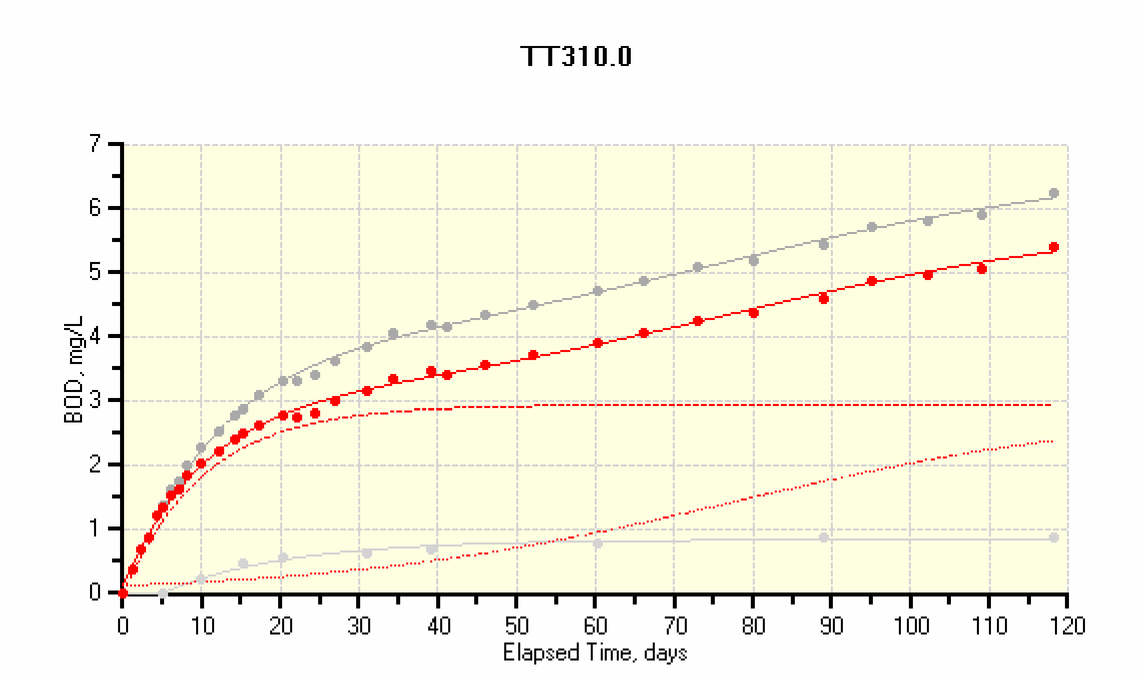


Figure 59: BOD rates for reservoir station TT314



TBOD First Order + Logistics Fit: FO BODu=2.94; KRate=0.097; f-ratio=2.60; Logis BODu=2.86; Kn=0.040; A=3.101; RMS Error=0.07

Figure 60: BOD rates for station TT310.0

The dual 1st order would not converge

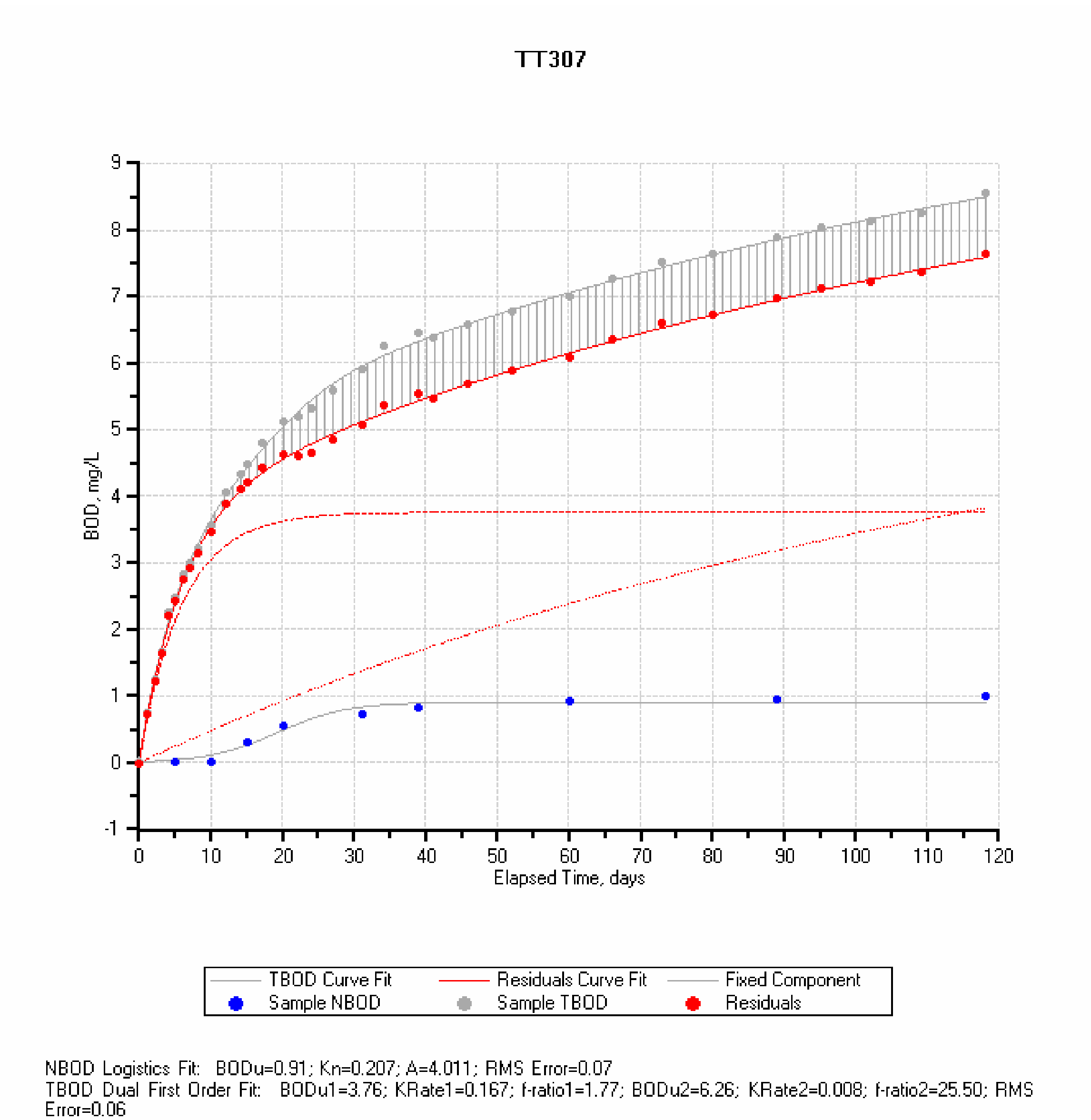


Figure 61: BOD rates for station TT307, Aliceville Dam forebay

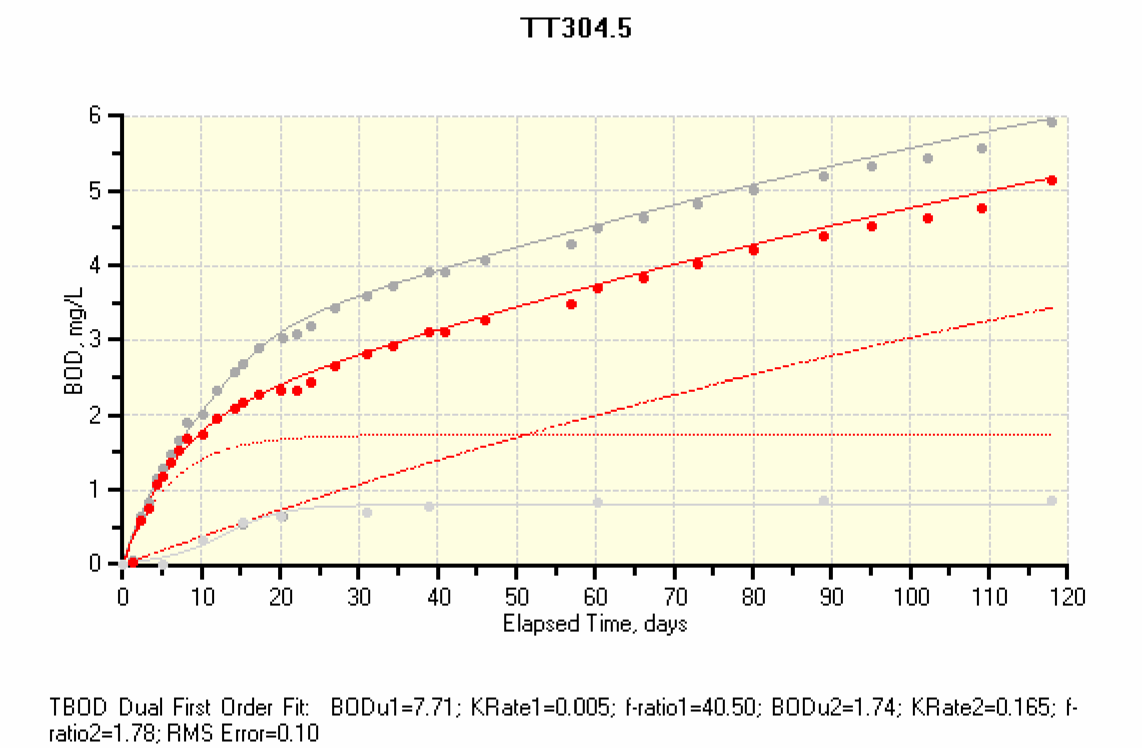


Figure 62: BOD rates for TT304.5 downstream of Bevill Lock and Dam (Aliceville Dam).

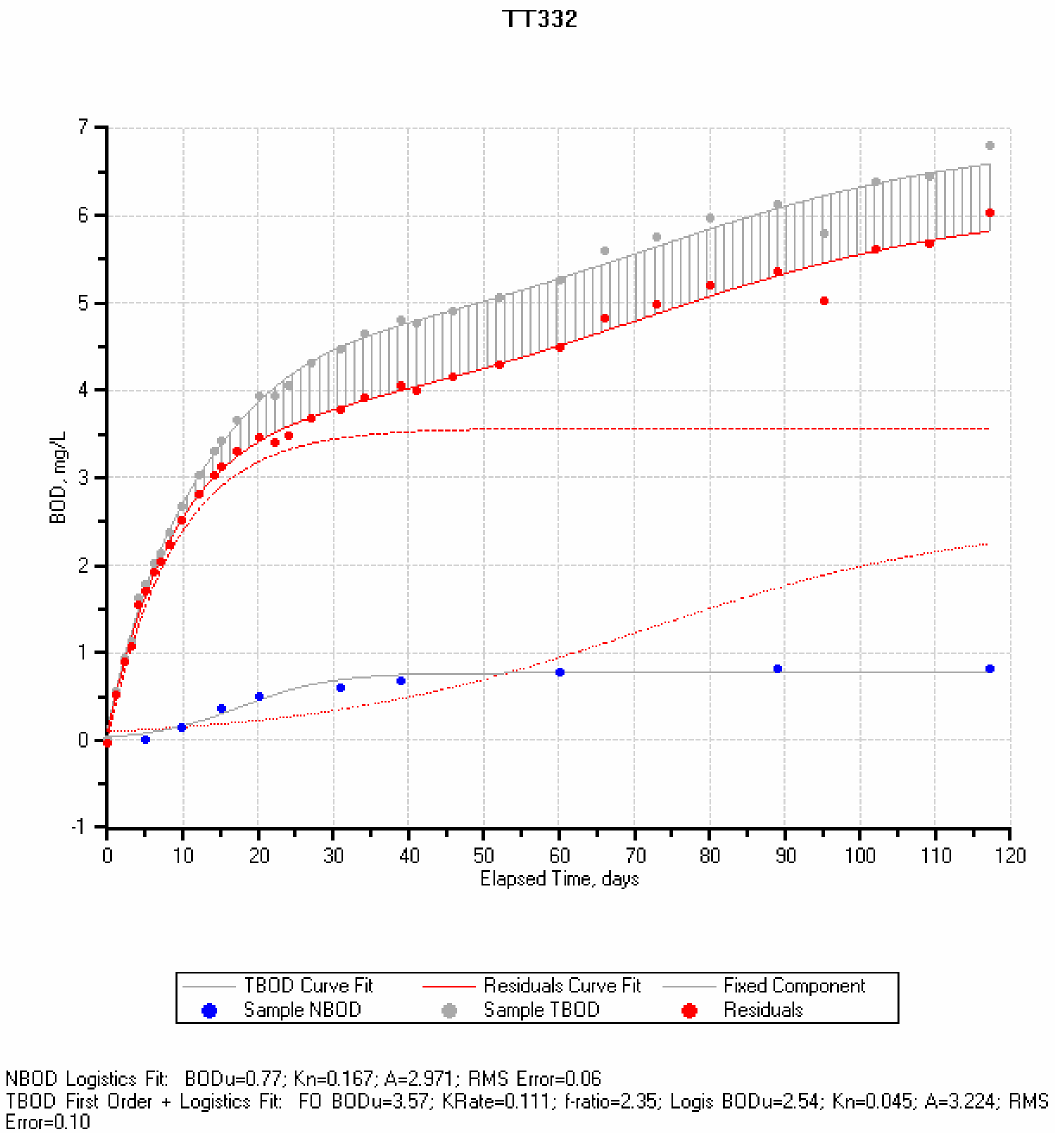
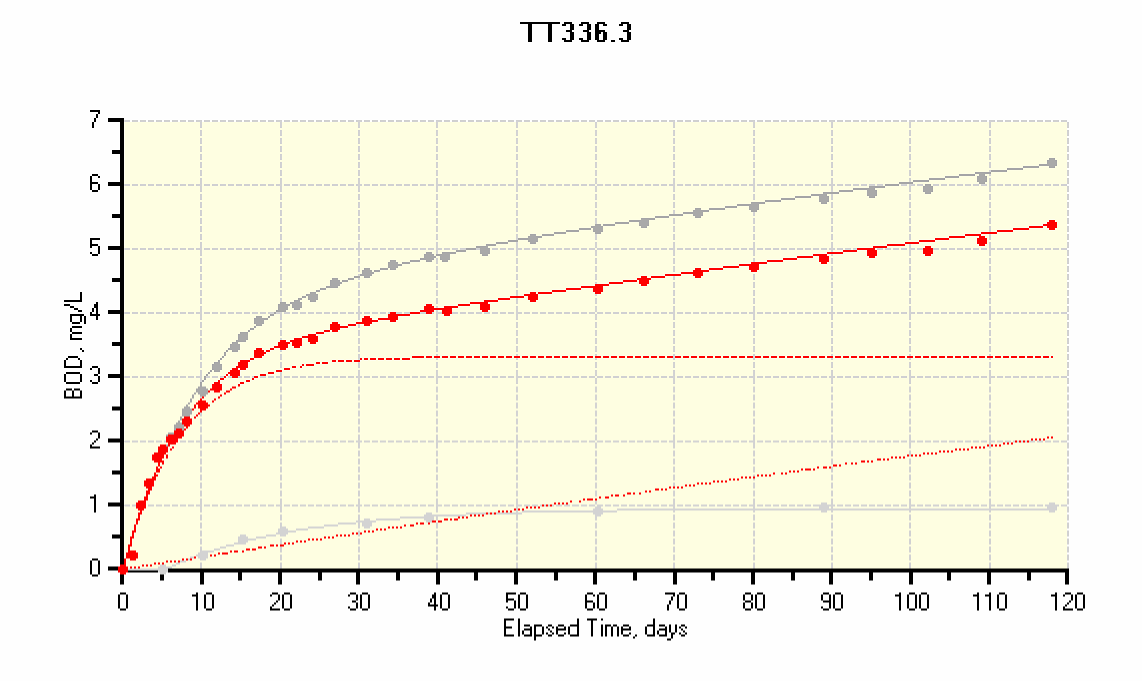


Figure 63: BOD rates for reservoir station TT332.



TBOD Dual First Order Fit: BODu1=3.32; KRate1=0.137; f-ratio1=2.02; BODu2=9.78; KRate2=0.002; f-ratio2=100.50; RMS Error=0.09

Figure 64: BOD rates for station TT336.3, in the Columbus pool above Stennis Dam.

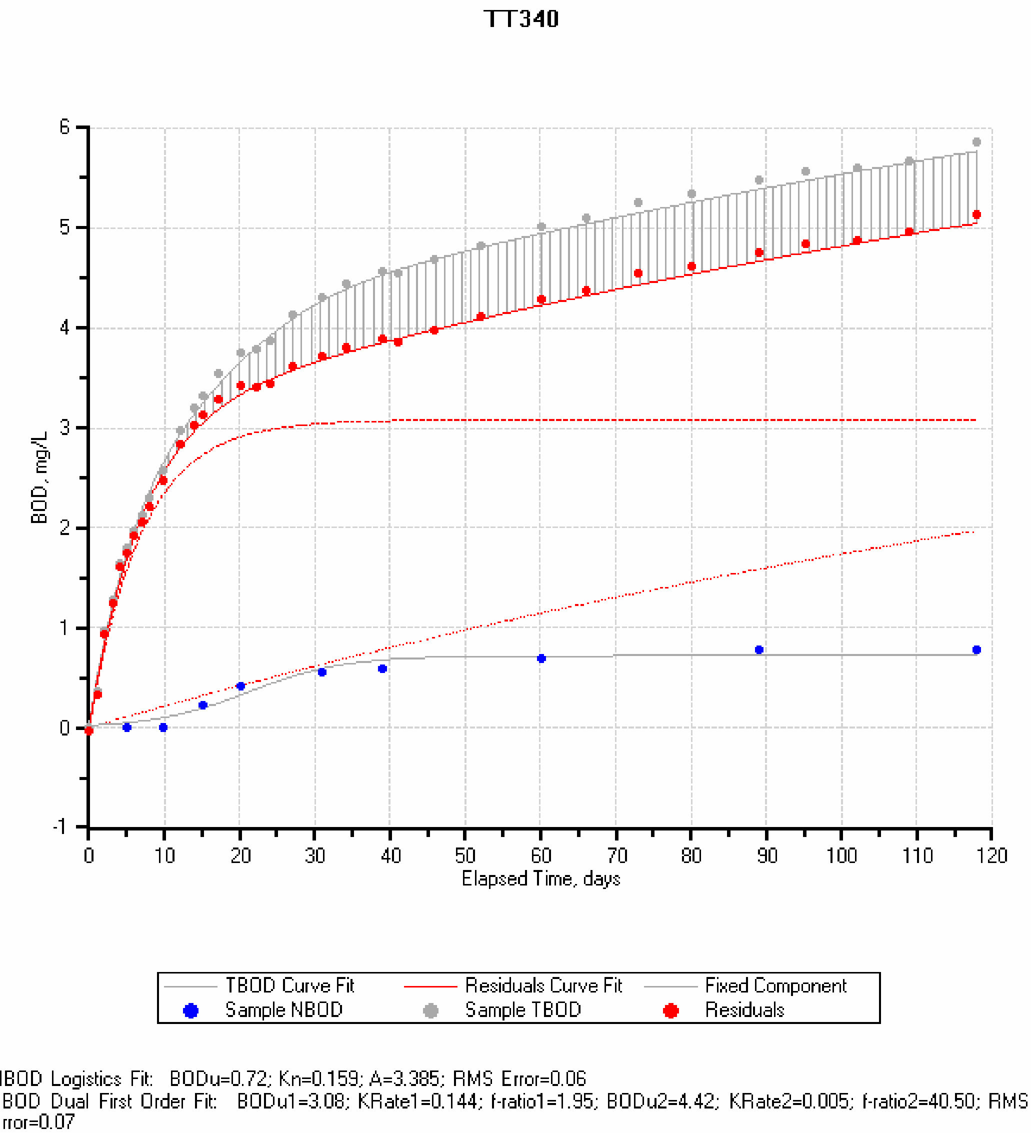


Figure 65: BOD rates for Columbus reservoir station TT340.

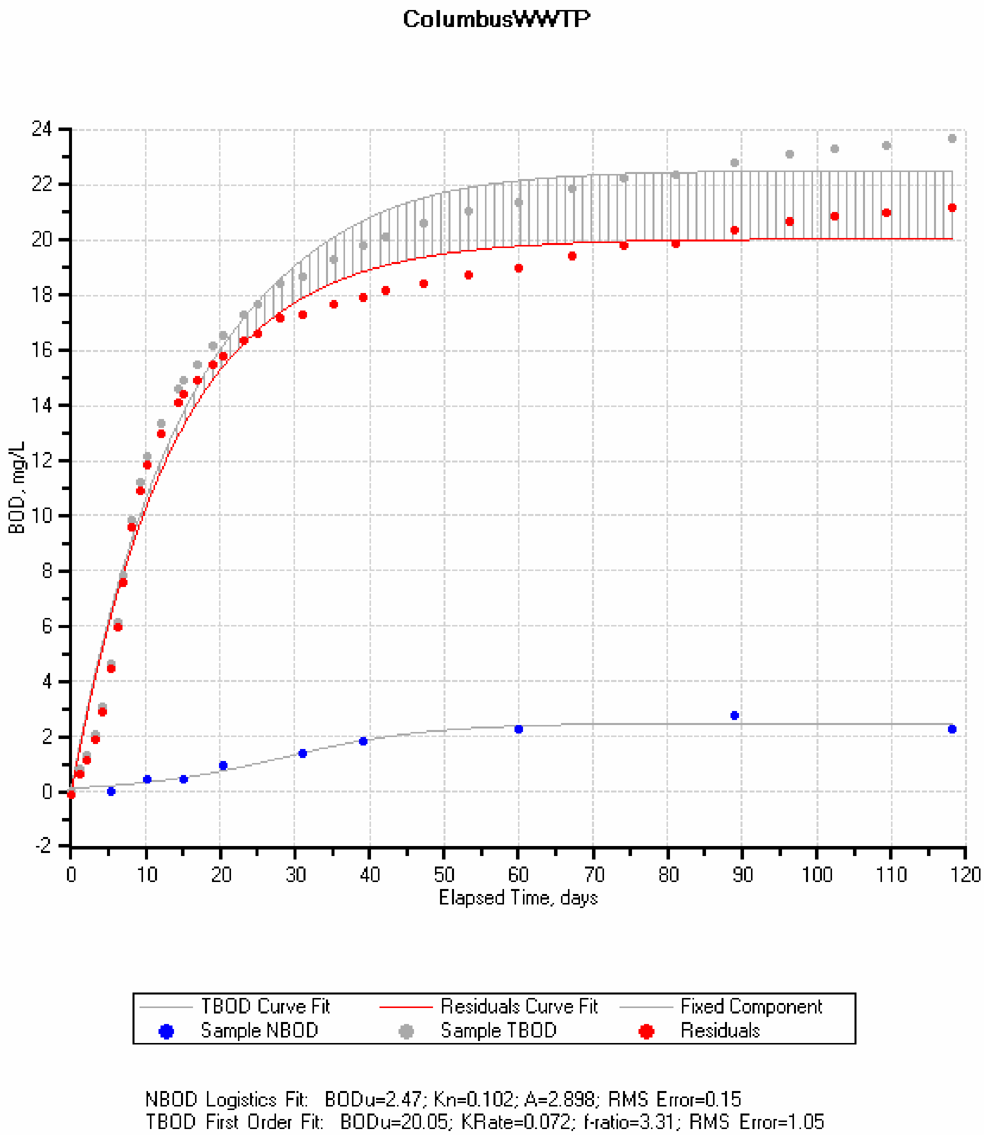


Figure 66: BOD rates for Columbus WWTP discharge.

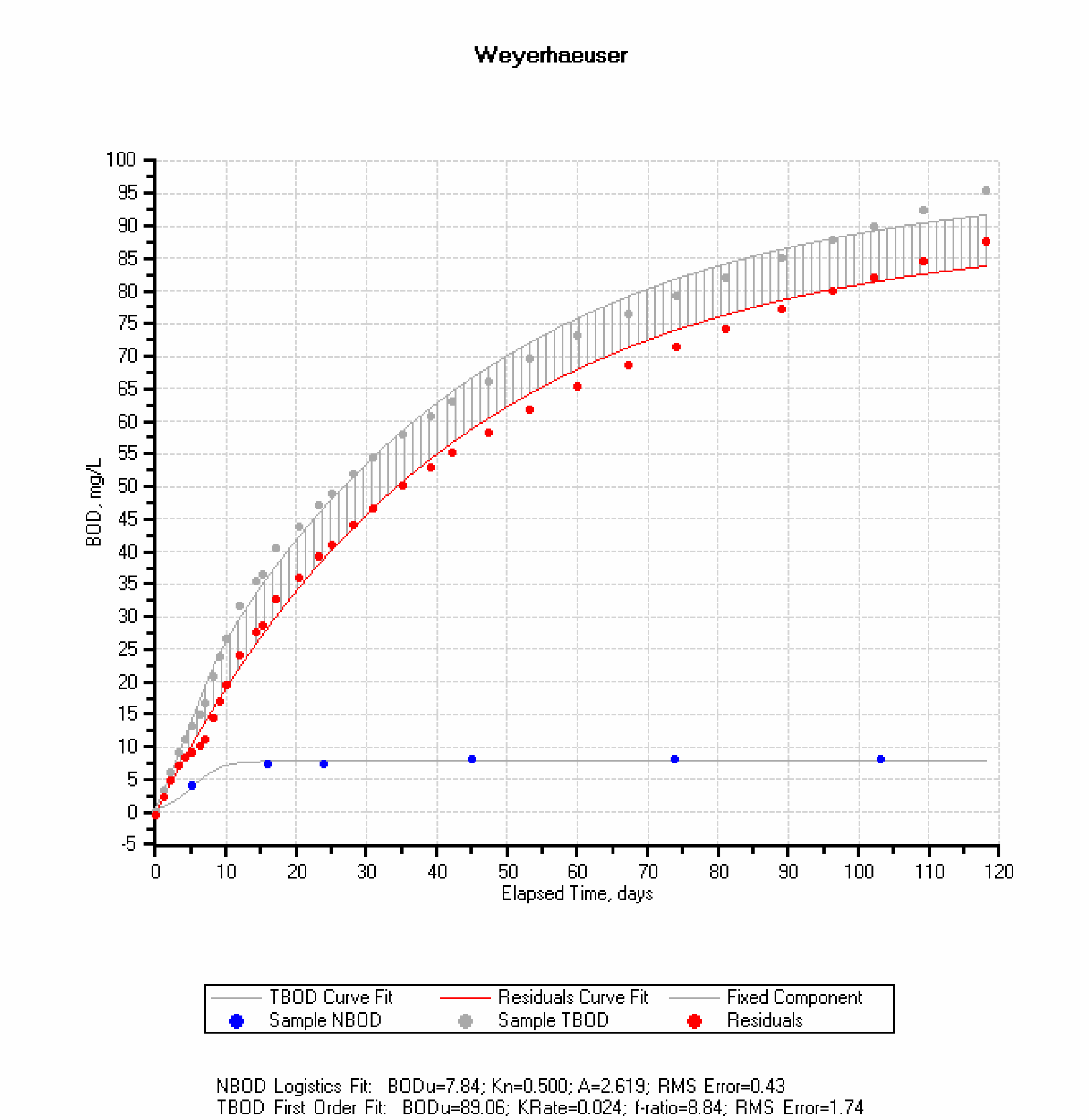


Figure 67: BOD rates for Weyerhaeuser discharge.

Tenn Tom LTBOD

Sta no.	BOD1	k1	BOD2	k2	RMS
TT 340.0	2.97	0.156	3.26	0.009	0.06
TT 336.3	3.32	0.137	9.78	0.002	0.09
TT 332.4	3.03	0.145	13.83	0.002	0.1
TT 327.7	3.41	0.164	3.5	0.014	0.07
TT 324.4	4.91	0.013	3.99	0.185	0.1
TT 319.6	3.27	0.195	4.7	0.013	0.09
TT 314.7	2.45	0.125	5.72	0.008	0.09
TT 310.0	2.94	0.097	2.86*	0.04	0.07

TT 307.3	5.74	0.009	3.75	0.172	0.06
TT 304.5	7.71	0.005	1.74	0.165	0.1

*Log fit

Appendix B Tombigbee River and Aliceville Reservoir: Three Dimensional Hydrodynamic Modeling Report

Tombigbee River and Aliceville Reservoir: Three Dimensional Hydrodynamic Modeling Report

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June 7, 2007

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1 INTRODUCTION

Aliceville Reservoir is located on the Tombigbee River near the state border of Alabama and Mississippi as shown in Figure 1.1. The reservoir water surface elevation is maintained at ~136 ft National Geodetic Vertical Datum (NGVD) by regulating upstream inflow through the Stennis Dam and downstream outflow through the Bevill Dam by the U.S. Army Corps of Engineers. It is 27.9 miles long from the Stennis Dam to the Bevill Dam.

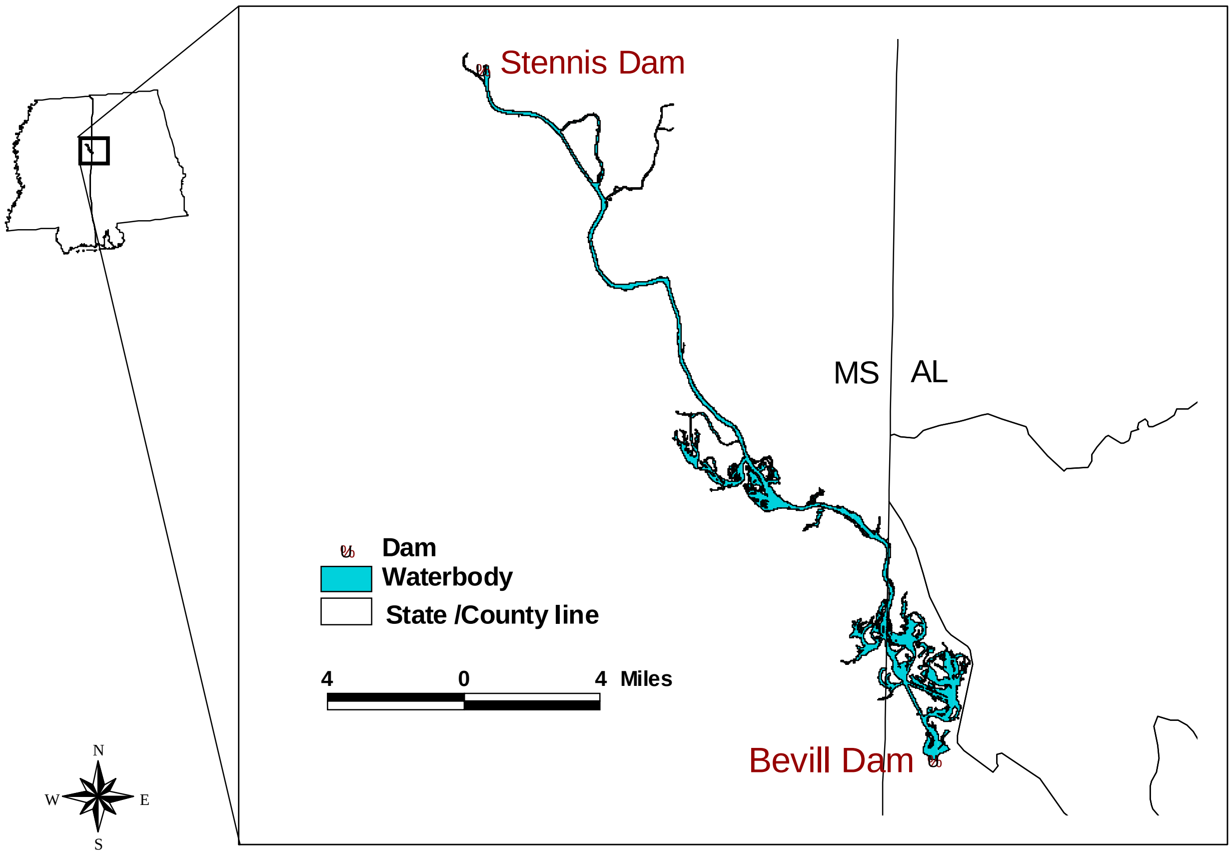

Figure 1.1 Locations of the Tombigbee River and Aliceville Reservoir

The list of impaired waters created under section 303(d) of the 1972 Clean Water Act (CWA) includes parts of Aliceville Reservoir impaired by low dissolved oxygen (DO). The CWA mandates an application of a Total Maximum Daily Load (TMDL) as a framework to scientifically understand and control the sources of pollutants that impair water quality and create detrimental conditions for aquatic ecosystems. TMDLs provide a restoration plan designed to reduce the amount of pollution contributing to the degradation of biotic and abiotic components of aquatic ecosystems.

TMDLs are, by definition, the sum of the individual waste load allocations for point and nonpoint sources and natural background with a margin of safety. The optimal solution of the waste load allocation problem typically requires the application of mathematical models to estimate unknown loads, relate loads to target concentrations, and to evaluate implementation strategies to achieve water quality targets.

In this report, a hydrodynamic model, Environmental Fluid Dynamics Code (EFDC), for the Tombigbee River and Aliceville Reservoir was developed and calibrated. A water quality model, Water Quality Analysis Simulation Program (WASP), will be developed by EPA Region 4 to predict the response of water quality on changes in management practices and use as support to TMDL decisions for the system.

2 MODEL BACKGROUND

2.1 EFDC Hydrodynamic Model

The three-dimensional hydrodynamics of the Tombigbee River and Aliceville Reservoir were modeled using the Environmental Fluid Dynamics Code (EFDC). EFDC is a hydrodynamic modeling package for simulating one-dimensional, two-dimensional, and three-dimensional flow and transport in surface water systems including: rivers, lakes, estuaries, reservoirs, wetlands, and near-shore to shelf scale coastal regions. The EFDC model was originally developed at the Virginia Institute of Marine Science for estuarine and coastal applications and is considered public domain software (Hamrick, 1992).

The physics of the EFDC model, and many aspects of the computational scheme, are equivalent to the widely used Blumberg-Mellor model (Blumberg & Mellor, 1987) and the U.S. Army Corps of Engineers' CH3D or Chesapeake Bay model (Johnson, et al., 1993). The EFDC model solves the three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable density fluid. Dynamically coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity, and temperature are also solved. The two turbulence parameter transport equations implement the Mellor-Yamada level 2.5-turbulence closure scheme (Mellor & Yamada, 1982; Galperin et al., 1988).

The EFDC model uses a stretched, or sigma, vertical coordinate and Cartesian or curvilinear, orthogonal horizontal coordinates. The numerical scheme employed in EFDC to solve the equations of motion uses second order accurate spatial finite differencing on a staggered or C grid. The model's time integration employs a second order accurate three-time level, finite difference scheme with an internal-external mode splitting procedure to separate the internal shear, or baroclinic mode, from the external free surface gravity wave, or barotropic mode.

The external mode solution is semi-implicit, and simultaneously computes the two-dimensional surface elevation field by a preconditioned conjugate gradient procedure. The external solution is completed by the calculation of the depth average barotropic velocities using the new surface elevation field. The model's semi-implicit external solution allows large time steps that are constrained only by the stability criteria of the explicit central difference, or high order upwind advection scheme (Smolarkiewicz and Margolin, 1993) used for the nonlinear accelerations. Horizontal boundary conditions for the external mode solution include options for simultaneously specifying the surface elevation only, the characteristic of an incoming wave (Bennett & McIntosh, 1982), free radiation of an outgoing wave (Bennett, 1976; Blumberg & Kantha, 1985) or the normal volumetric flux on arbitrary portions of the boundary.

The EFDC model's internal momentum equation solution, at the same time step as the external, is implicit with respect to vertical diffusion. The internal solution of the momentum equations is in terms of the vertical profile of shear stress and velocity shear, which results in the simplest and most accurate form of the baroclinic pressure gradients and eliminates the over-determined character of alternate internal mode formulations. Time splitting inherent in the three time level scheme is controlled by periodic insertion of a second order accurate two time level trapezoidal step.

3 EFDC Hydrodynamic Model Development

3.1 Hydrodynamic Data

The simulation period for the purposes of the calibration study was from July 2003 through September 2005. The data utilized in the development of hydrodynamic boundary conditions and for the purpose of model calibration consists of the following types:

- Measured water surface elevation and water temperature data;
- Measured dam and stream flows; and
- Measured meteorological data.

The data used in this study were archived within the Water Resources Database (WRDB) platform as a project specific dataset. As a part of the TMDL Toolbox, the WRDB software is available to download for free at www.wrdb.com.

3.1.1 Water Surface Elevation and Temperature

Daily reservoir water surface elevation data from 2003 through 2005 were collected at the forebay of Aliceville Reservoir as shown in Figure 3.1. The normal pool elevation is maintained at 136 ft NGVD by regulating inflow from the upstream through the Stennis Dam and outflow to the downstream through the Bevill Dam by the U.S. Army Corps of Engineers. Three water temperature monitoring stations in Figure 3.1 collected vertical temperature profile data in both 2003 and 2004.

3.1.2 Flows

Daily flows at the tailraces of the Stennis Dam and the Bevill Dam were collected by the two USGS stations (USGS 02441390 and 02444160) during 2003 through 2005. One of the major upstream inflows; the Luxapilila Creek daily flow, was also collected by the USGS station (02443500) during 2003 through 2005. The three flow stations are indicated in Figure 3.2.

3.1.3 Meteorological Data

Meteorological data collected for rainfall, air temperature, relative humidity, solar radiation, barometric pressure, wind speed, wind direction, and evaporation are essential parameters in hydrodynamic modeling. The weather station at Golden Triangle Regional Airport was considered in this application (Figure 3.3).

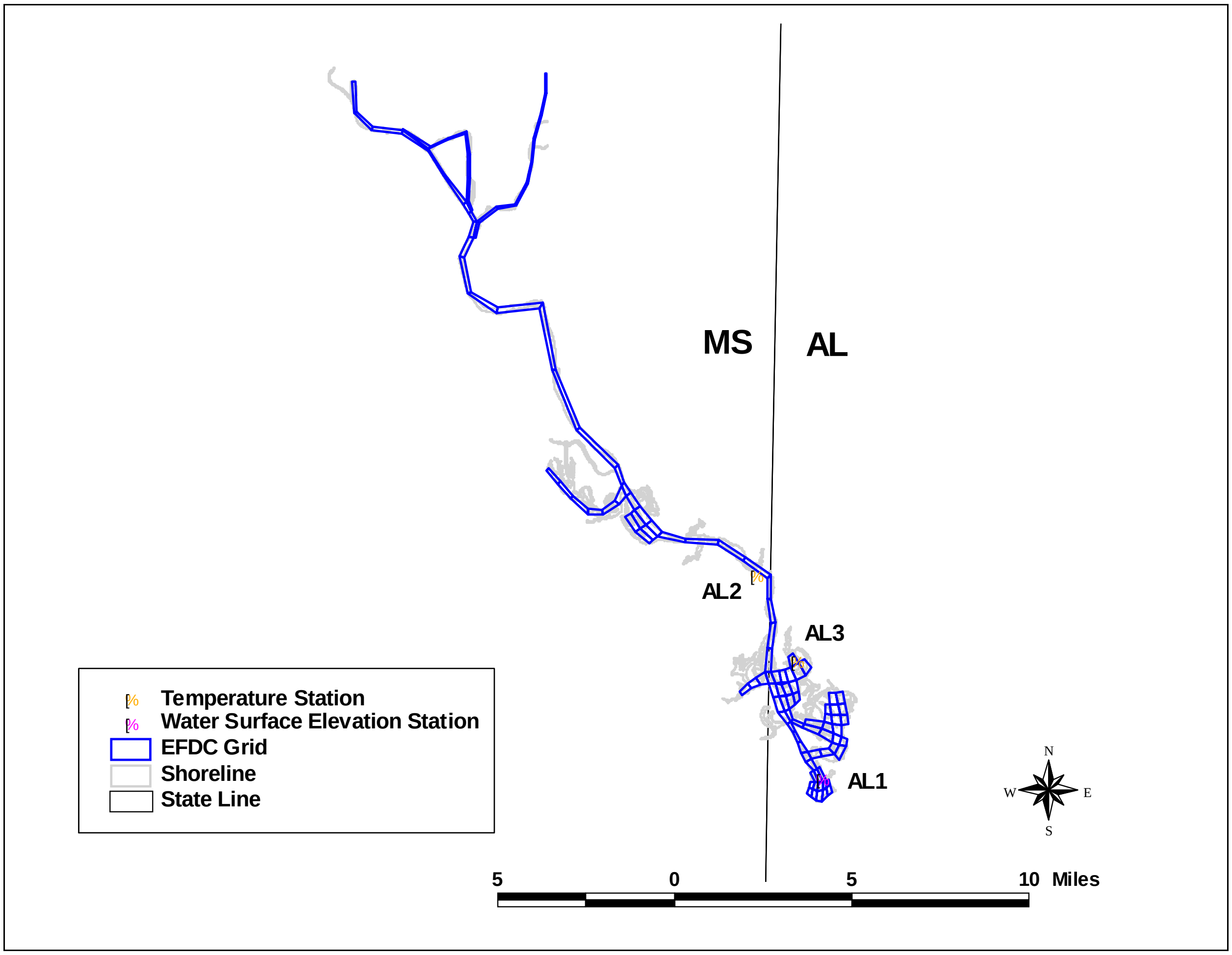

Figure 3.1 Locations of the Water Surface Elevation and Temperature Stations

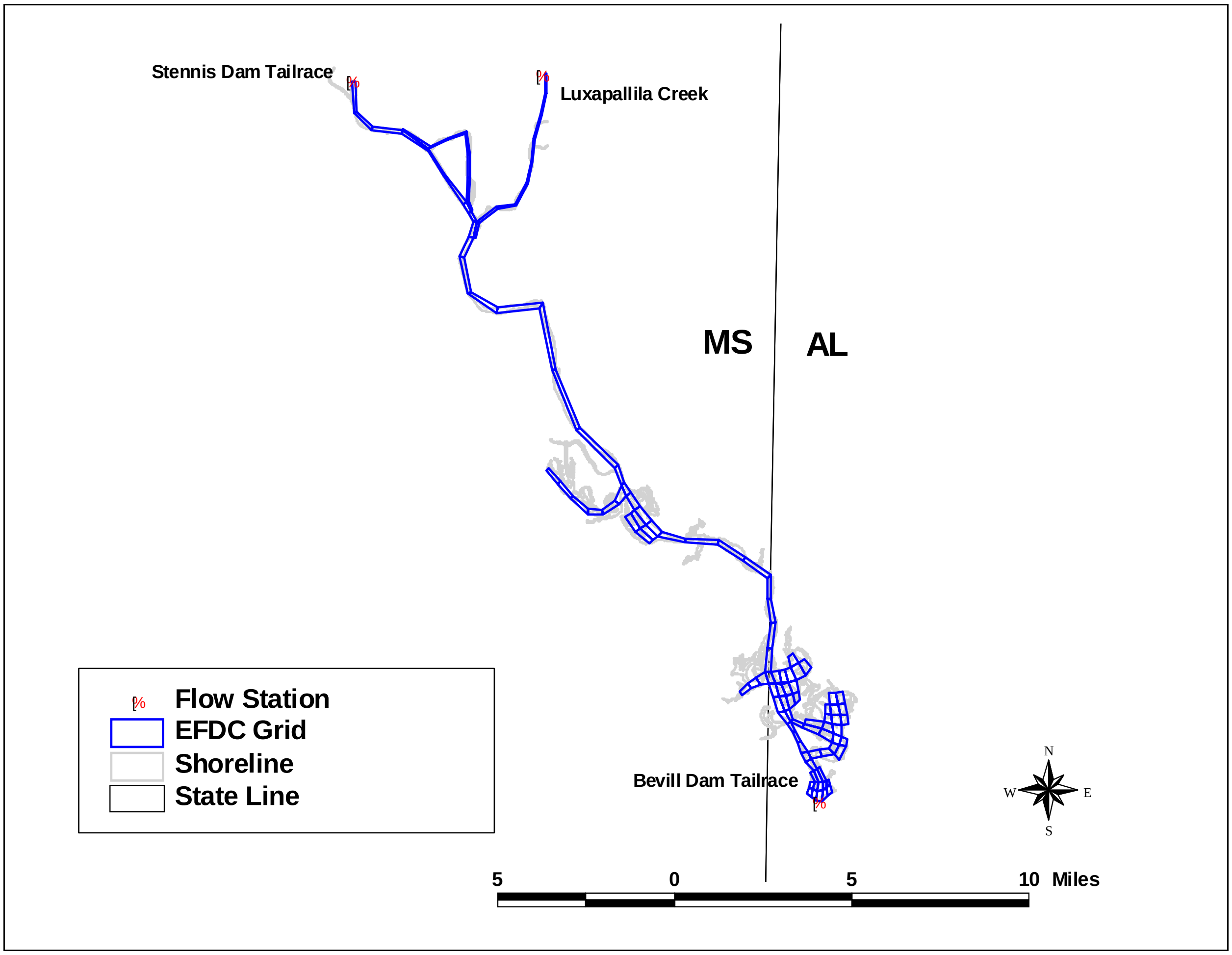

Figure 3.2 Locations of Flow Stations

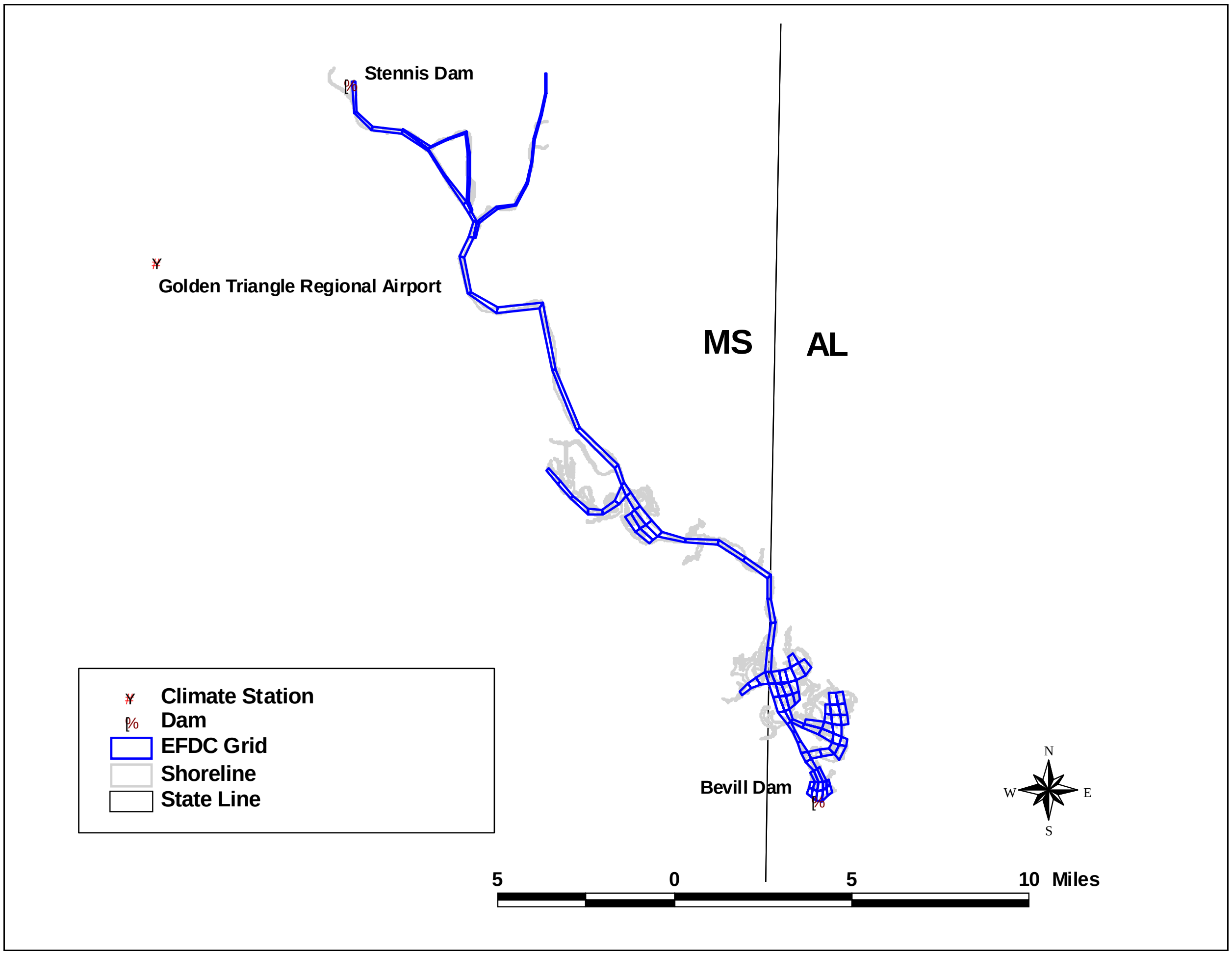

Figure 3.3 Location of the Weather Station

3.2 Bathymetry

The development of bathymetry is important to adequately simulate hydrodynamics of water temperature and water surface elevation. The channel cross-section data at 1000-foot intervals collected by the U.S. Army Corps of Engineers covers the Tombigbee River and main channel of Aliceville Reservoir as shown in Figure 3.4. The Alabama Department of Environmental Management (ADEM) complemented the bathymetric data by collecting cross-sectional profiles outside the main channel as also shown on Figure 3.4. Figure 3.5 presents the interpolated bathymetry based on these available cross-section data.

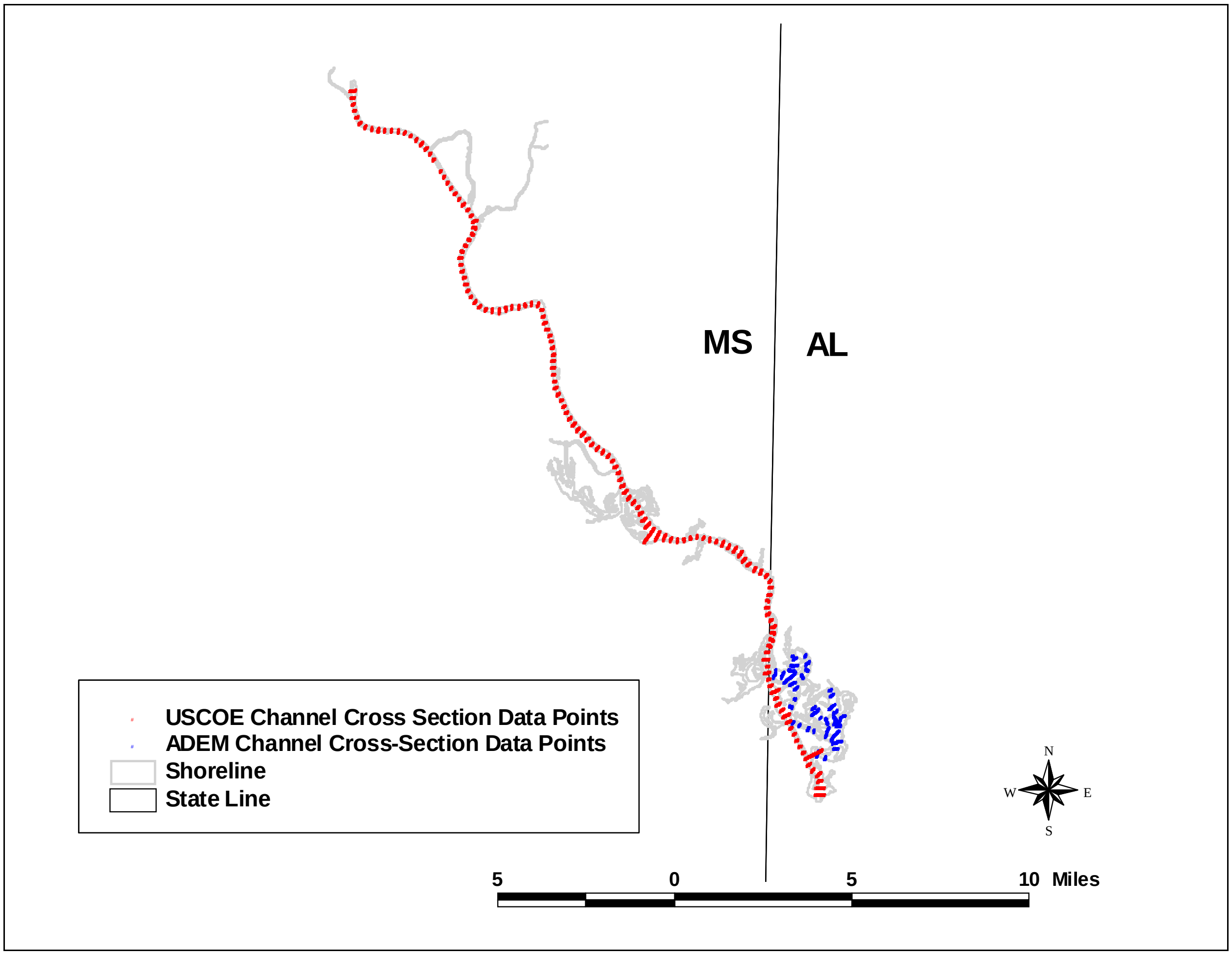

Figure 3.4 Locations of the Channel Cross-Section Data

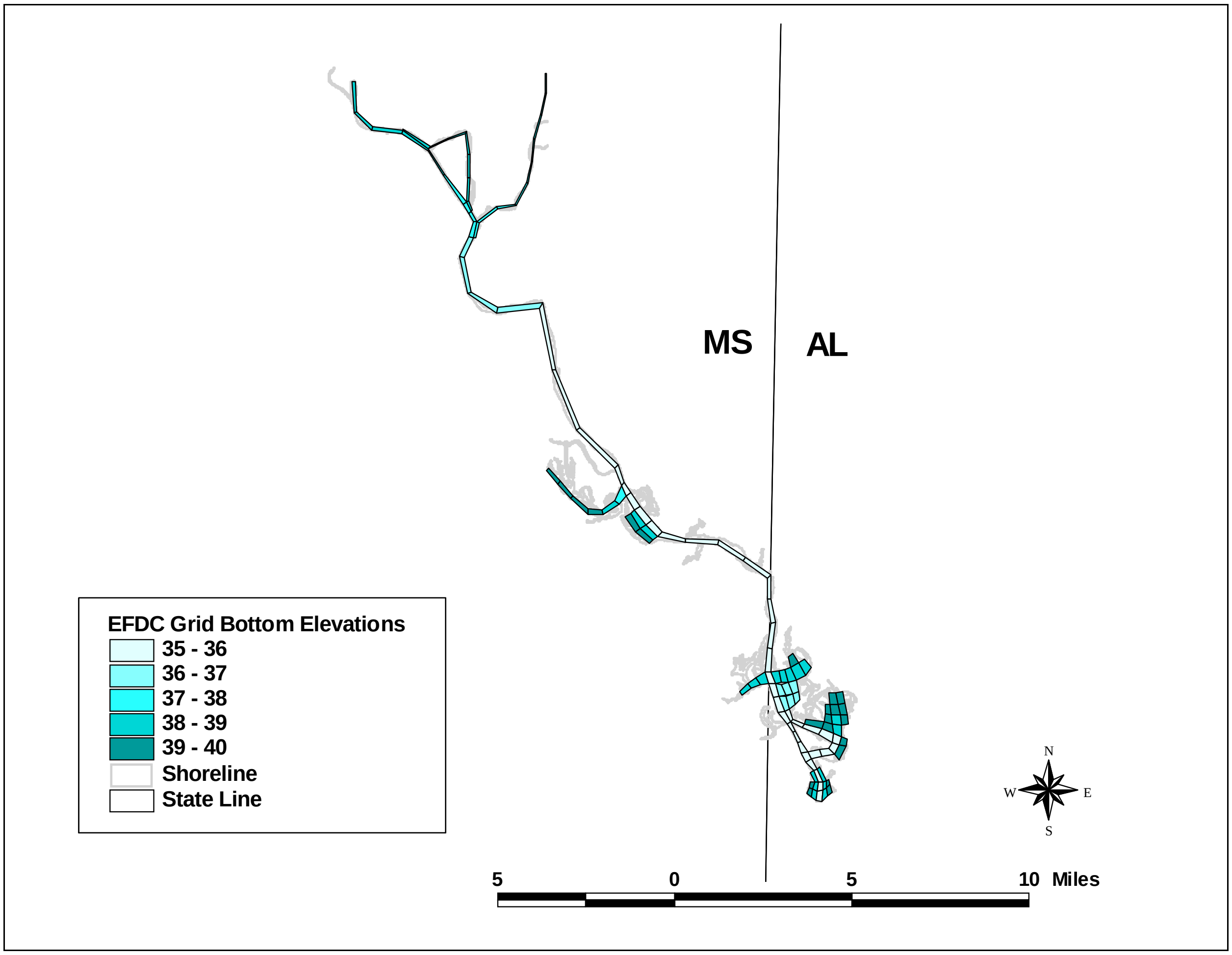

Figure 3.5 Interpolated Tombigbee River and Aliceville Reservoir Bathymetry

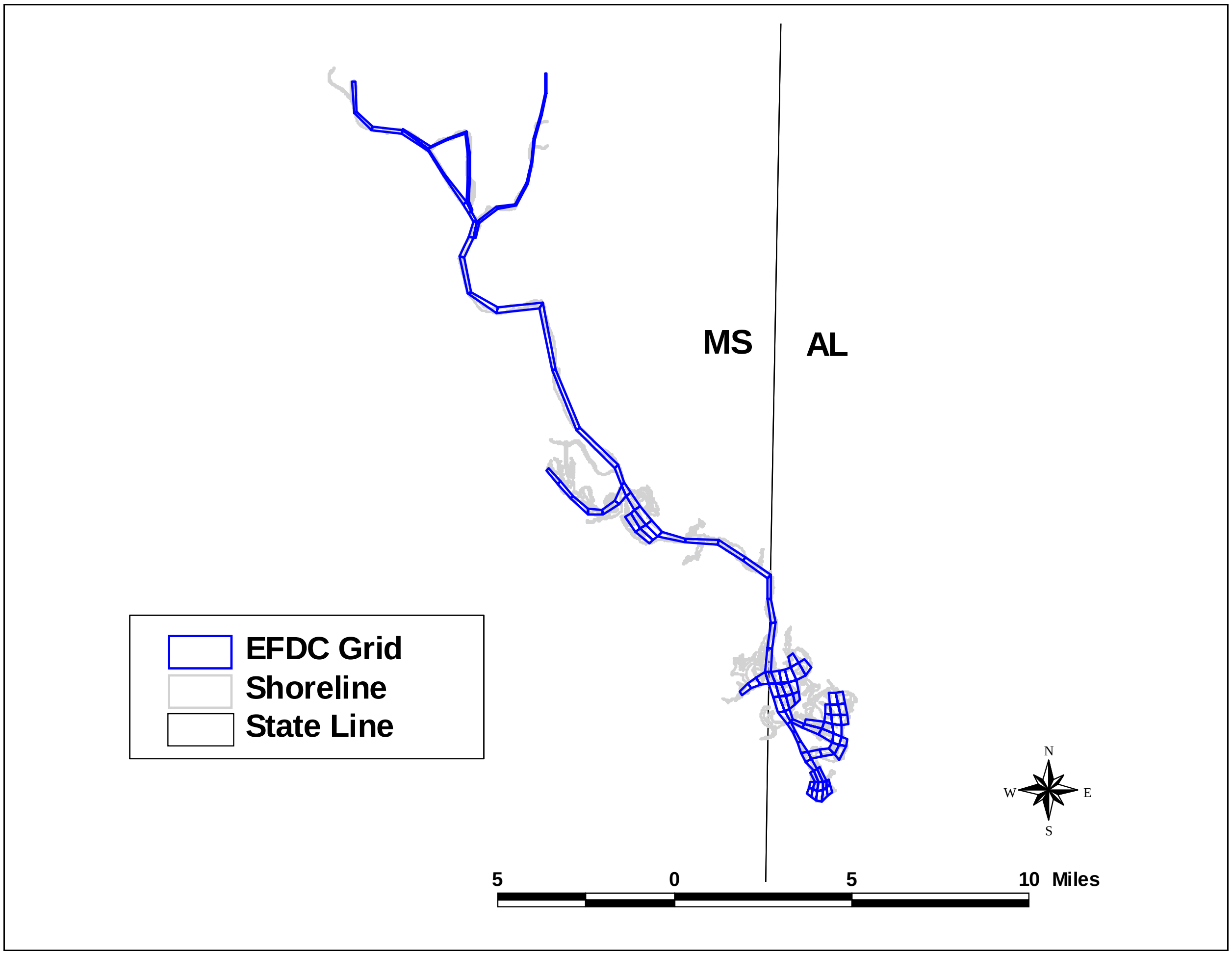

Figure 3.6 Tombigbee River and Aliceville Reservoir Model Grid

3.3 Segmentation of Tombigbee River and Aliceville Reservoir

The Tombigbee River and Aliceville Reservoir were segmented into curvilinear orthogonal computational grid cells representing horizontal dimension for the hydrodynamic and water quality model. To better simulate the hydrodynamics of the main channel and deeper pools in the reservoir, a Z grid system was used.

The waterbody was segmented into 113 horizontal grid cells (Figure 3.6) with a total of 327 segments overall in the Z grid system, with the maximum being 5 layers.

3.4 Hydrodynamic Boundary Conditions and Point Source Discharges

Deterministic time variable models predict conditions within the computational domain of the model based upon perturbations within the model grid caused by outside forcing functions. These forcing functions need to be described to the model in order to predict the perturbations that occur within the model grid. The forcing functions that are required in the hydrodynamic model for the Tombigbee River and Aliceville Reservoir include:

- Freshwater inflow and outflow;
- Meteorological conditions (wind, solar radiation, etc.);
- Inflow freshwater temperature.

For calibration purposes, time dependent or constant values for each of these parameters must be applied at each of the appropriate boundaries for the entire model simulation period. These values were applied at all of the boundaries within the system including:

- Stennis Dam tailrace
- Bevill Dam tailrace
- Luxapilila Creek.

The following presents a discussion of how the boundary conditions were determined and applied for the hydrodynamic model calibration simulations.

3.4.1 Freshwater Flows

Two upstream incoming flows into the model domain are the Stennis Dam tailrace flow (USGS 02441390) and Luxapilila Creek flow (USGS 02443500). Figure 3.7 shows the upstream inflows to the model system. It should be noted that the missing data from October through December 2005 were replaced with the averaged flows respectively. The downstream outflow at Bevill Dam tailrace (USGS 02444160) is presented in Figure 3.8.

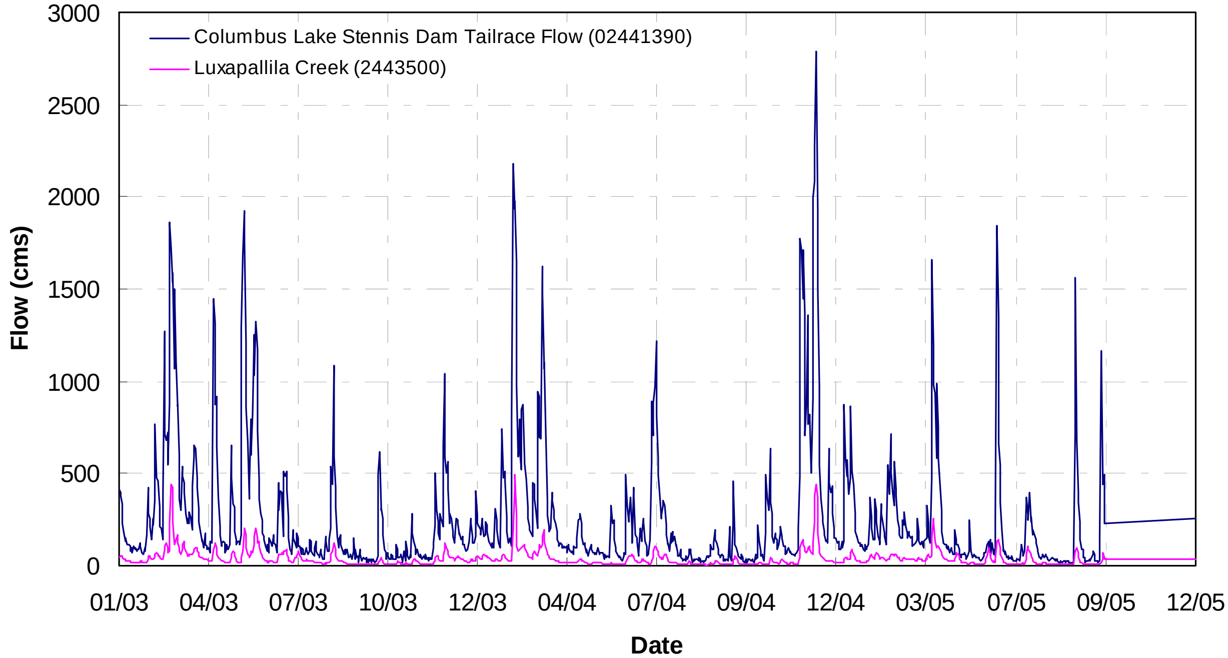

Figure 3.7 Upstream Inflows Used in the EFDC Model

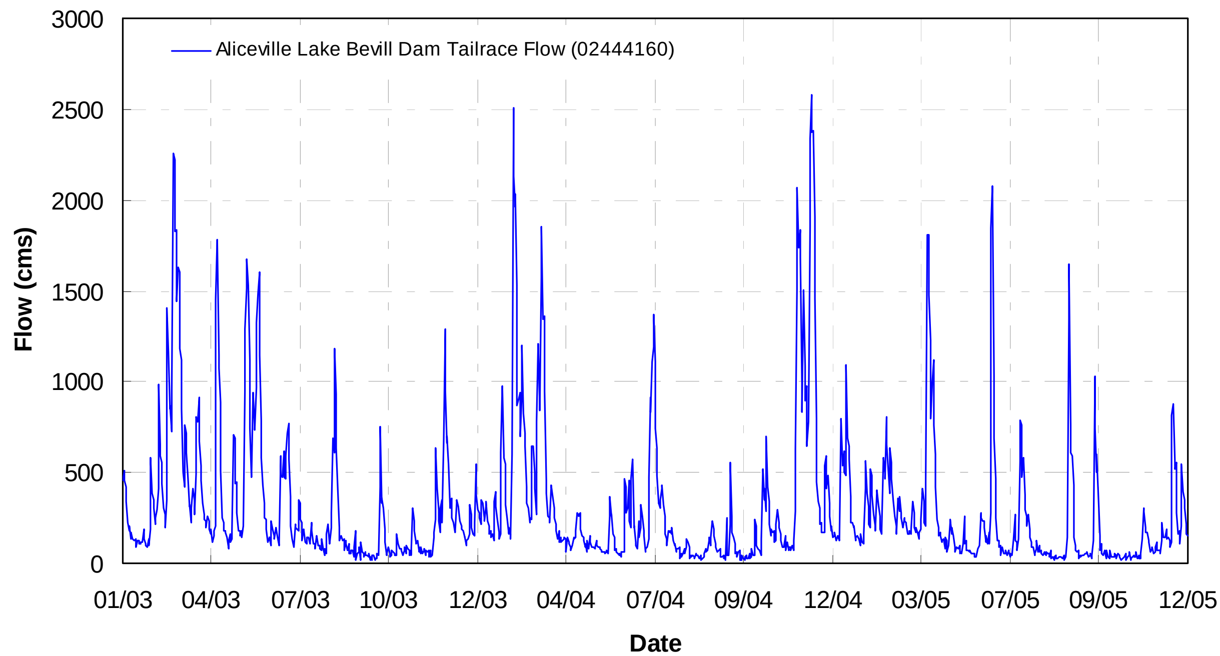

Figure 3.8 Downstream Outflow Initially Used in the EFDC Model

A simple comparison between the total inflow and the total outflow found that a significant flow difference was observed during the simulation period while the variation of the water surface elevations at the forebay was small. The flow difference is simply due to unknown watershed flows, river and lake evaporation, and surface water interaction with groundwater. To compensate the difference and achieve a better estimate of the mass balance of the reservoir, area weighted watershed flows were included in the model. Final mass balance was achieved by using the Lake Flow Correction feature in the EFDC simulation.

3.4.2 Meteorological Conditions

The meteorological data needed for the hydrodynamic model calibration were obtained from the NOAA and NCDC from 2003 to 2005. Meteorological parameters that were collected at the Golden Triangle Regional Airport station and used in the modeling effort were air temperature, dew point temperature, cloud cover, precipitation, wind direction, and wind speed.

3.4.3 Inflow Water Temperature

Direct measurements of water temperature at the upstream boundaries (Stennis Dam tailrace and Luxapilila Creek) were not available. Initially, the daily water temperature measurements at the Weyerhaeuser Columbus Mill Intake shown in Figure 3.9 were used for the upstream boundaries. During the model calibration, the water temperatures at the upstream boundaries were linearly adjusted to better simulate water temperature profiles at the other temperature stations shown in Figure 3.1.

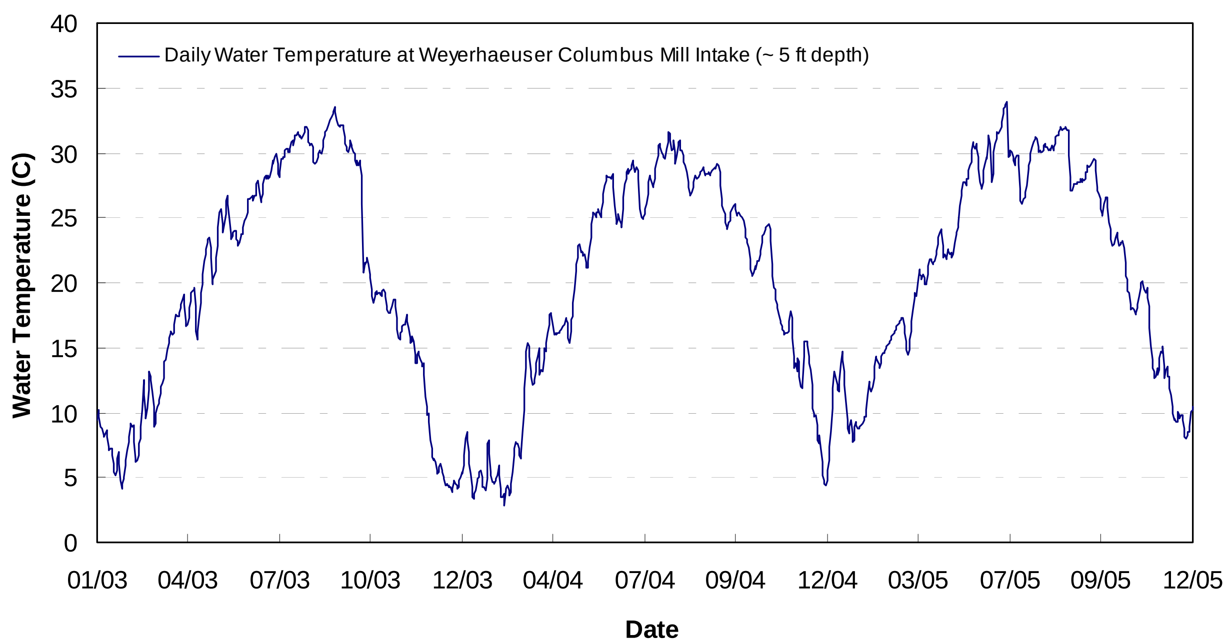

Figure 3.9 Water Temperature Initially Used in the EFDC Model for Upstream Inflows

3.4.4 Point Source Discharges

There are a series of industrial and municipal point sources discharging to the system. Compared to the upstream inflows from the Stennis Dam and Luxapilila Creek, the combined known point source flow is negligible, contributing less than 0.5% of the total upstream inflow. In the EFDC model, the point source flows were included. The upstream inflow water temperature data was used for the point sources since no point source temperature data were available.

3.5 Hydrodynamic Calibration

The calibration objectives for the hydrodynamic model were to adequately represent the physics of the system by propagating momentum and energy based upon freshwater inflow, solar energy, and wind. Another calibration objective was to have the ability to predict water temperature distribution, because it is important in adequately representing water quality of the system.

The water surface elevations and vertical water temperature profile data collected at the stations shown in Figure 3.1 were used in the model calibration.

3.5.1 Water Surface Elevations

Water surface elevations were calibrated to the known water surface elevation at the forebay of Aliceville Reservoir. With the Lake Flow Correction feature, the EFDC model calculated the average missing or added flow over the user-specified time period based on the mass balance equation for the target water surface elevation at the forebay for each time step. Then the model calculated flow was added into the model and re-run in the model. After several iterations, a good match between the simulated and the measured water surface elevation was obtained. Figure 3.10 shows the calibrated and the measured water surface elevations for the period of March 2003 through September 2005.

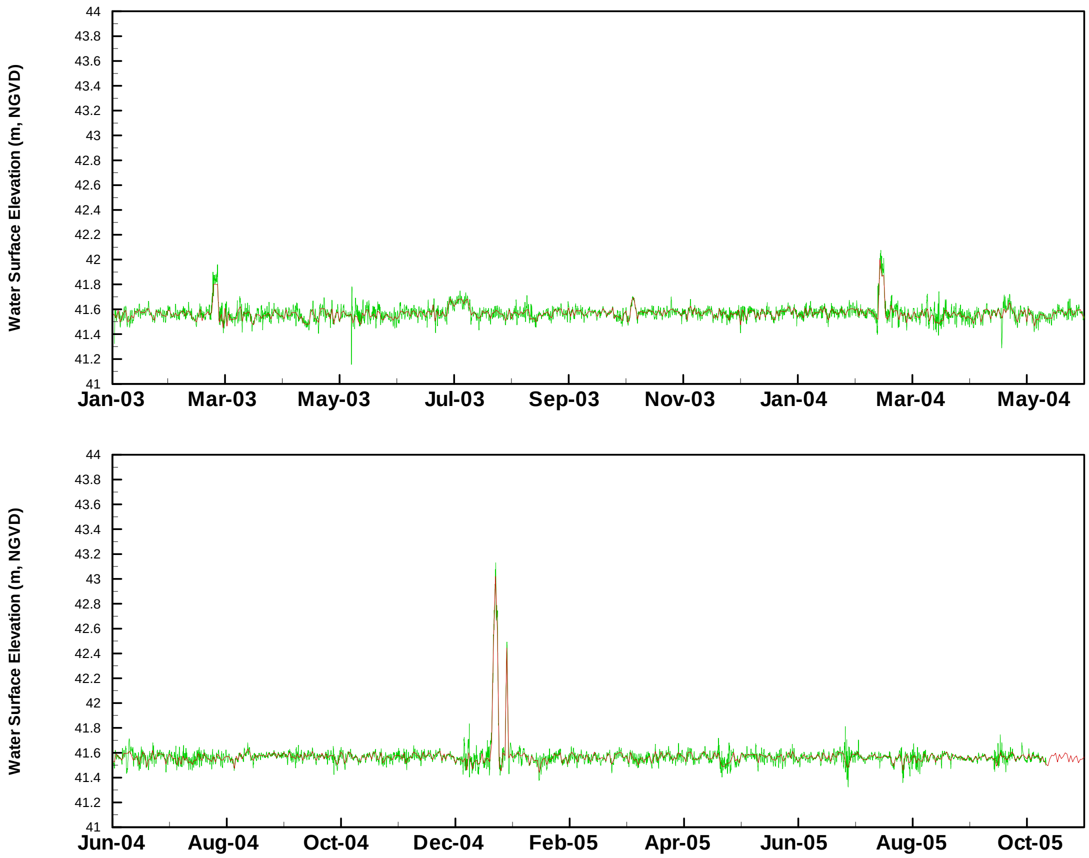

Figure 3.10 Comparison of Water Surface Elevation between the Measured and the Simulated at the Forebay of Aliceville Reservoir

3.5.2 Water Temperature

The simulated and measured vertical temperature profiles are presented in Figures 3.11 through 3.16. It is observed that the calibrated water temperatures at Station AL1 (forebay) and Station AL2 at the upstream end of the main channel match the measured data reasonably well. However, for Station AL3, which is located where water is relatively stagnant, the simulated water temperatures were consistently overestimated by approximately two to four degrees Celsius. The bathymetry in this region was represented in the model as shallower than surrounding areas, which could be causing the overheating in this area. Cooler groundwater seepage could also be occurring in this region that is not being simulated by the model.

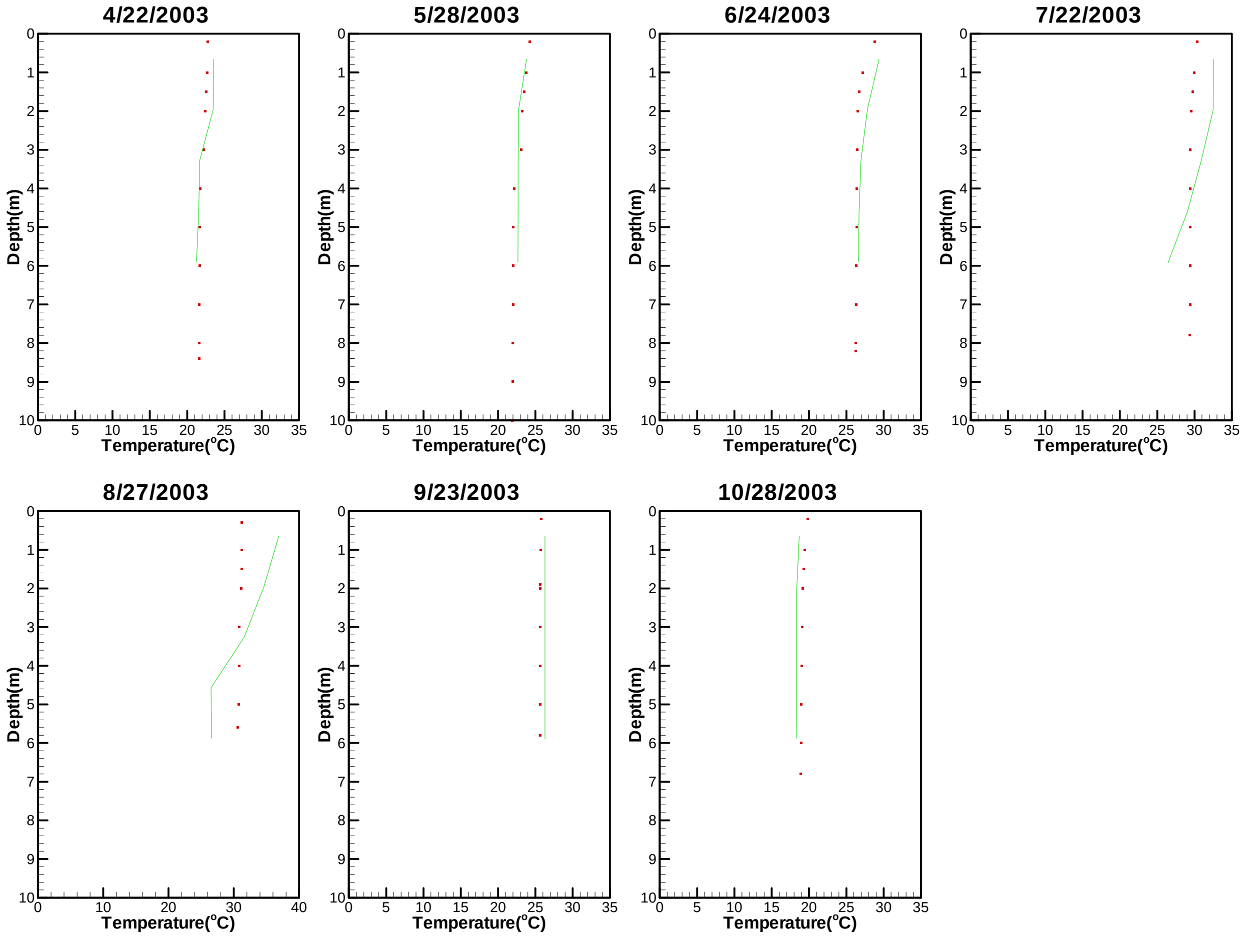

Figure 3.11 Comparison of 2003 Measured and Simulated Water Temperature Profiles at Station AL1

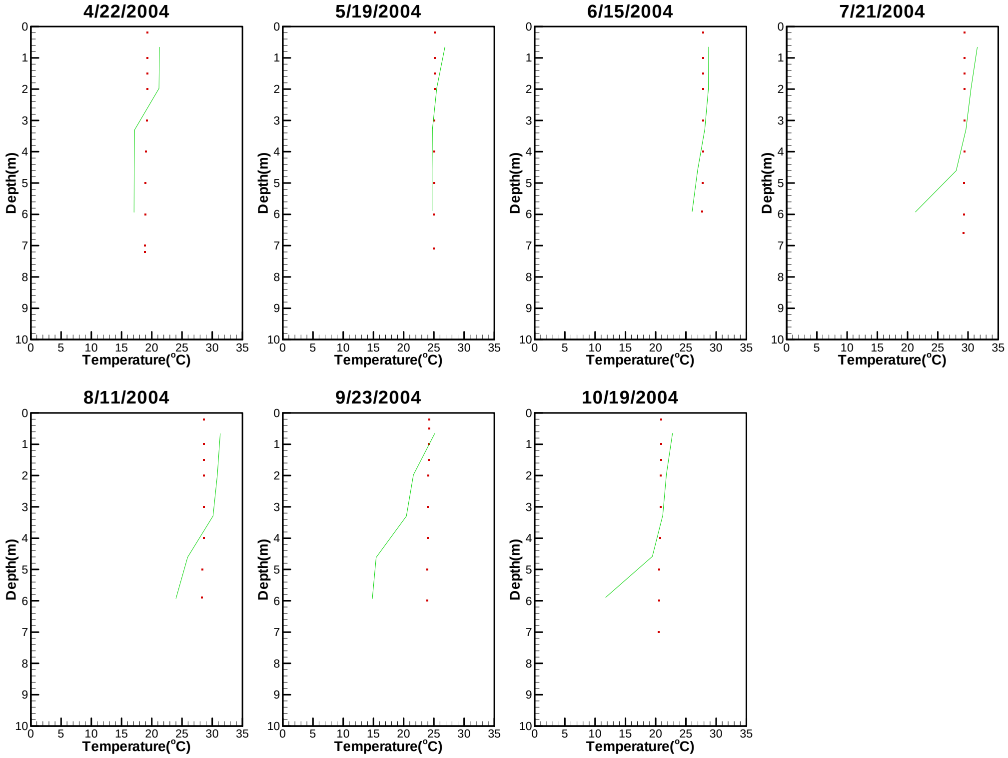

Figure 3.12 Comparison of 2004 Measured and Simulated Water Temperature Profiles at Station AL1

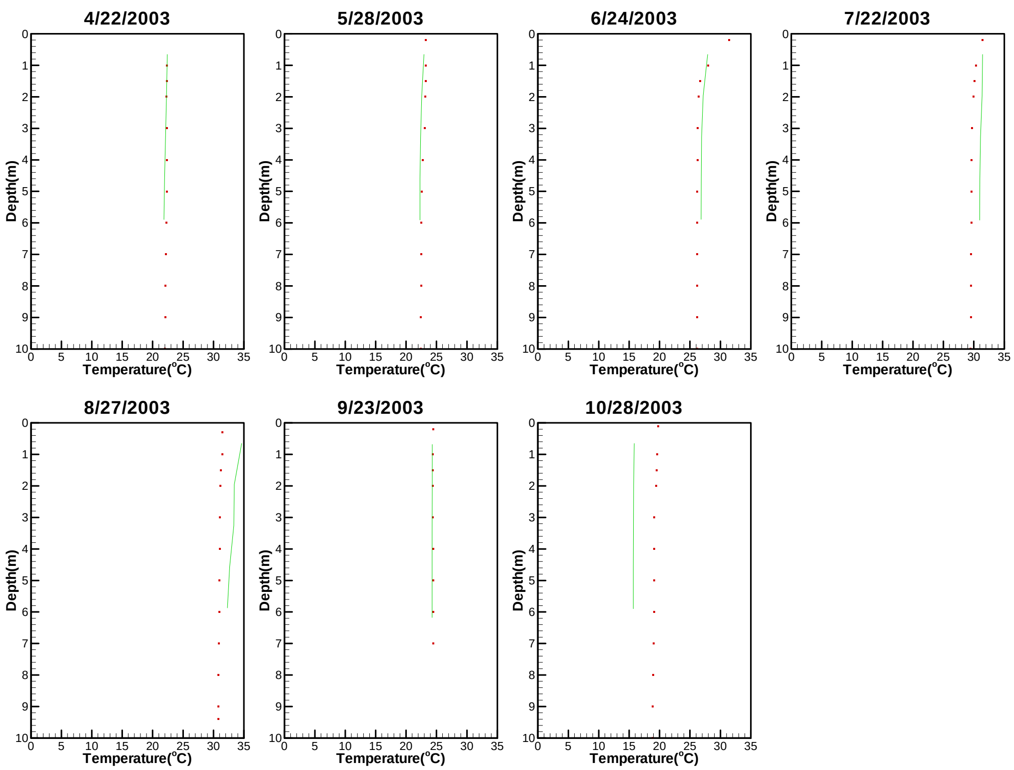

Figure 3.13 Comparison of 2003 Measured and Simulated Water Temperature Profiles at Station AL2

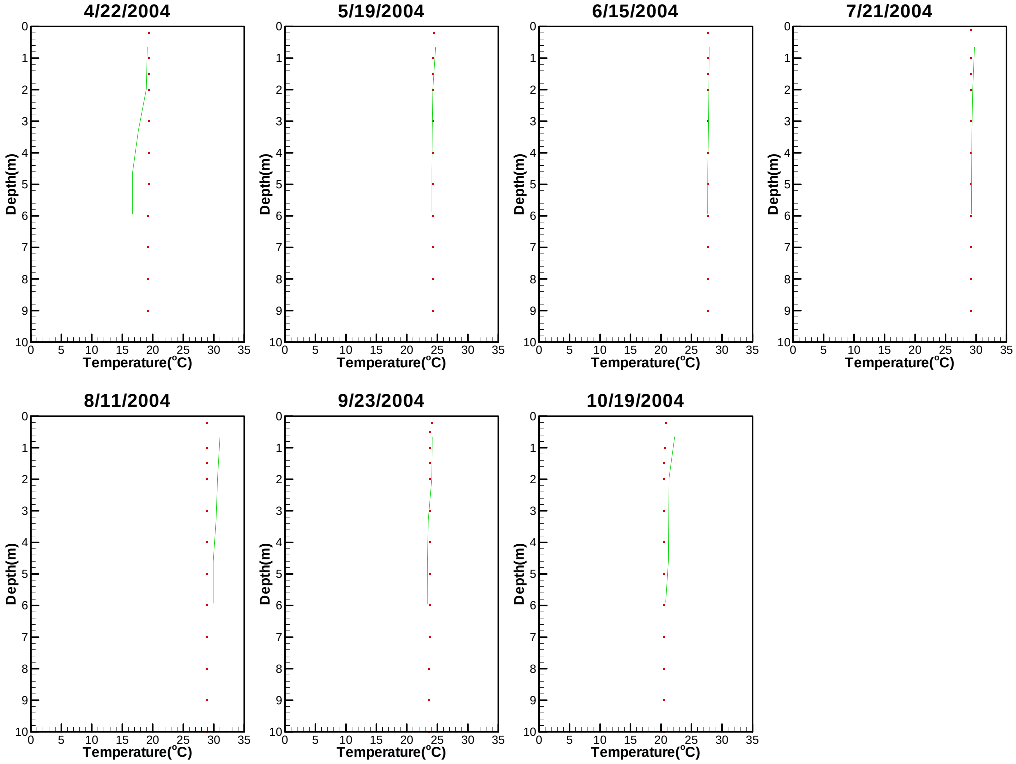

Figure 3.14 Comparison of 2004 Measured and Simulated Water Temperature Profiles at Station AL2

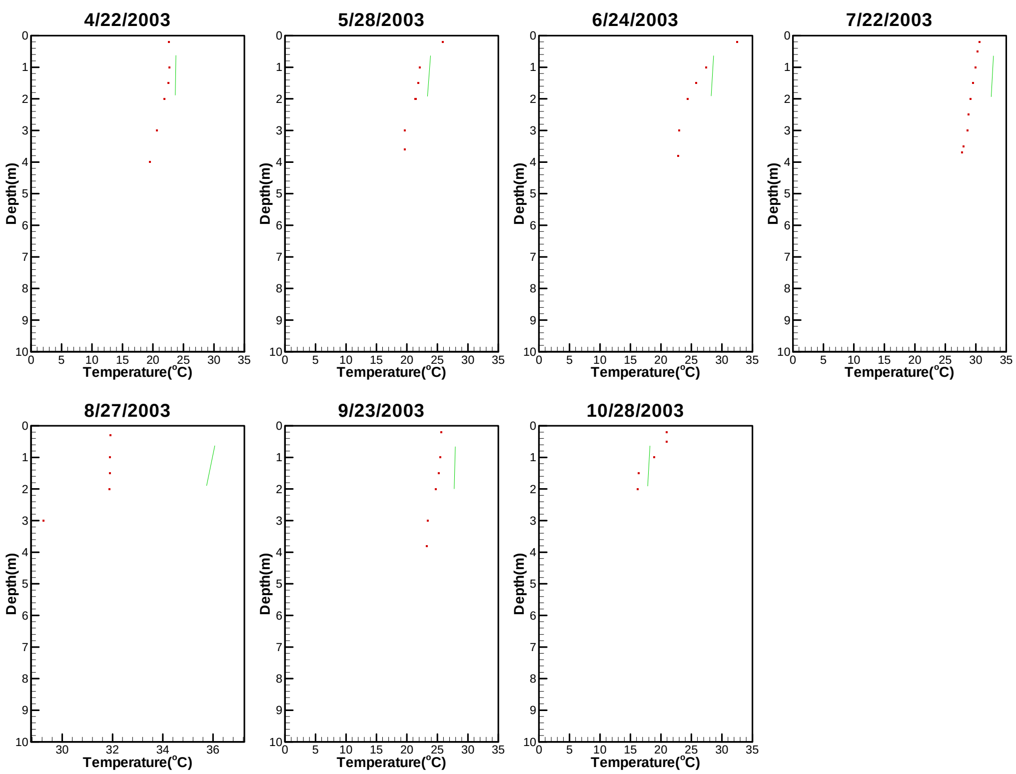

Figure 3.15 Comparison of 2003 Measured and Simulated Water Temperature Profiles at Station AL3

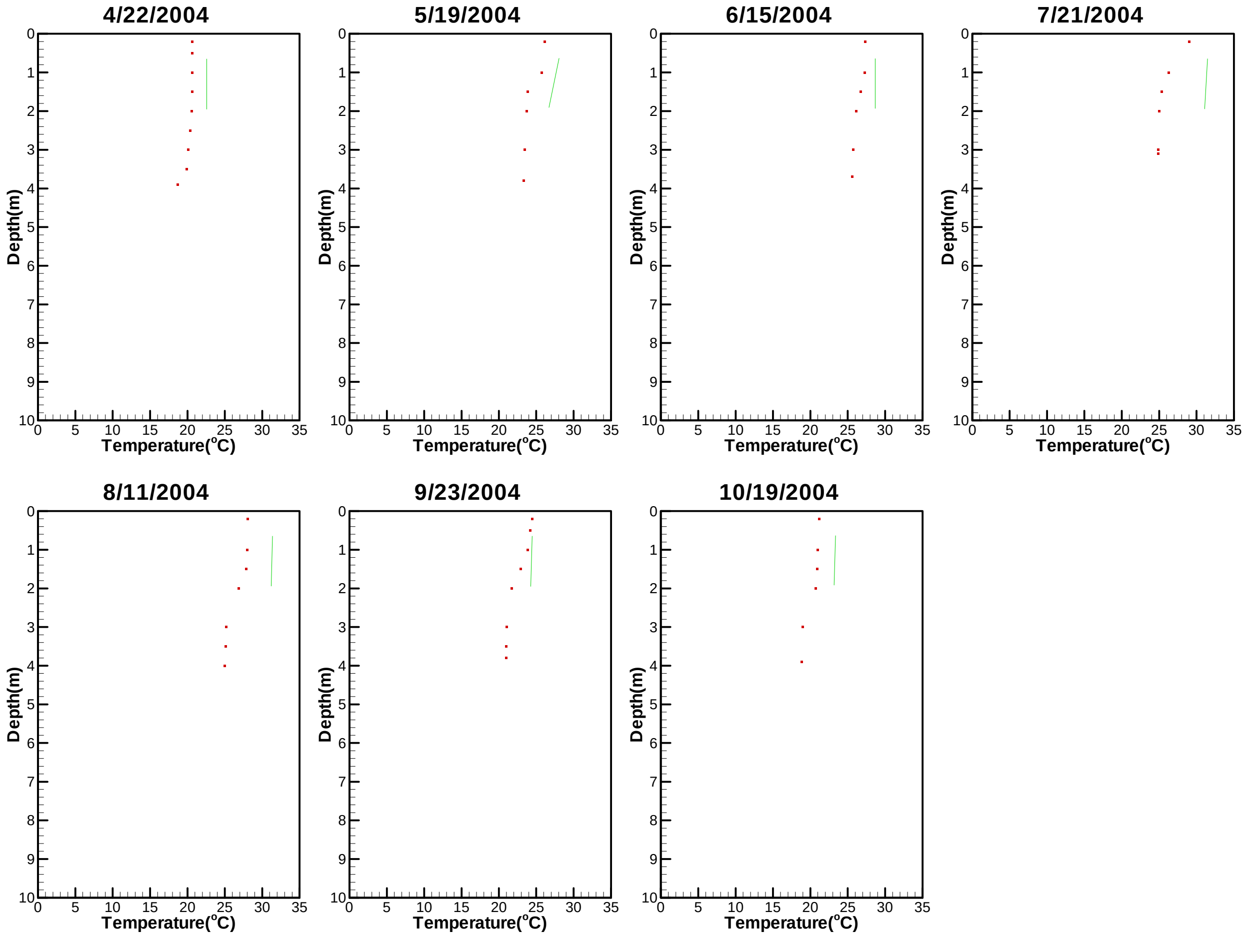

Figure 3.16 Comparison of 2004 Measured and Simulated Water Temperature Profiles at Station AL3

4.0 SUMMARY AND CONCLUSIONS

The Tombigbee River and Aliceville Reservoir hydrodynamic EFDC model was developed to simulate the hydrodynamic flow and water temperature distribution in order to adequately represent the water quality in the system. The model was calibrated to the water surface elevations at the forebay of the Aliceville Reservoir and the vertical water temperature profiles at three stations in the system. Overall, reasonably good calibrations of both the water surface elevations and water temperatures were achieved.

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